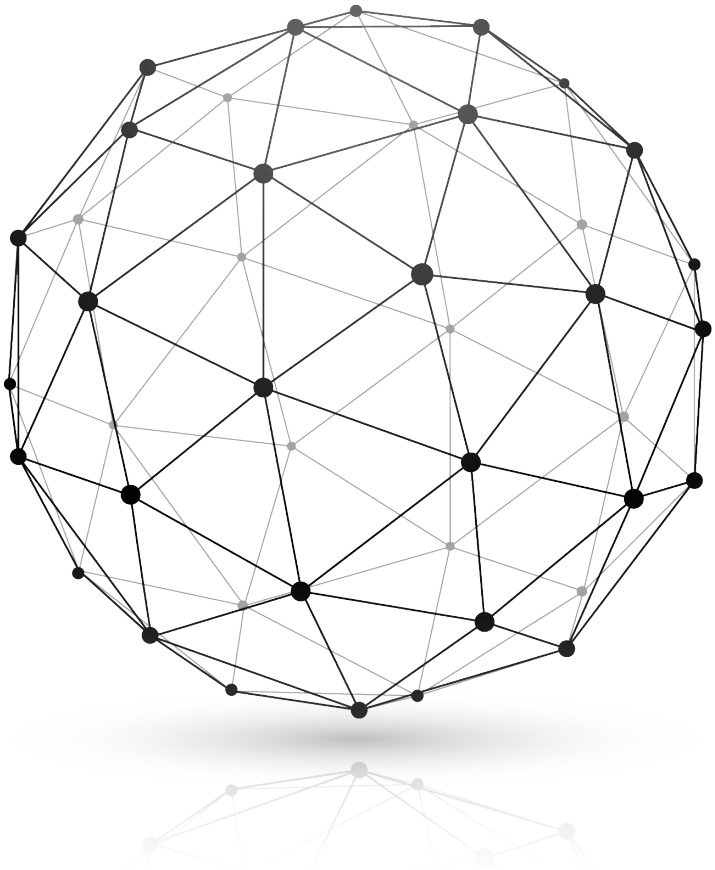
A blockchain-based business process to securitise mortgages

Master Thesis
MSc. Management of Technology



Writing this thesis was like blockchain: First it was all hype; then it collapsed; and in the end, we were all surprised it worked out.

-Ben van Rossum-

Colophon

Titel:
A blockchain-based business process to securitize mortgages

Author:
Ben van Rossum
4087836

University:
TU Delft
Faculty of Technology, Policy and Management

Cooperating Company:
PwC Amsterdam
Risk Assurance

First supervisor:
Dr.Ir. Z. Roosenboom-Kwee, section: Economics of Technology & Innovation
Second supervisor:
Prof.Dr.Ir. M.F.W.H.A. Janssen, section: Information and Communication Technology
Company supervisor:
Drs. L.K. Hartholt, section: Risk Assurance

Acknowledgements

I would like to address my gratitude and thanks to everyone for all support to complete my Master Thesis as part of the MSc Management of Technology programme.

First of all, I would like to express my gratitude for my coach, Zenlin Rosenboom-Kwee, and my co-reader, Marijn Janssen, for their guidance, patience and continuous support throughout the entire thesis process. My thesis and its quality has been improved by their comments, feedback and discussions, which inspired me to use and gain new insights to accomplish my thesis.

Likewise, I would like to thank my thesis supervisor at PwC, Bert Hartholt, who gave me the chance to accomplish my thesis at PwC, gave valuable tips and introduced me to contacts to come into contact with relevant respondents. In addition, I enjoyed our many discussions and conversations in the coffee corner.

Furthermore, I am grateful for having the opportunity to write my thesis at the Financial Services department of Risk Assurance PwC, which helped me a lot to get access to large-scaled companies across The Netherlands and provided me with a comfortable office and environment to write my thesis. Also, I learned a lot about PwC and its experts and enjoyed being a part of the team.

Moreover, writing this thesis has been a challenging, but pleasant experience for me. I have learned a lot about the implementation of blockchain in the securitisation business process. In addition, I really enjoyed that all hours spend in literature came to life by conducting the interviews and by watching how different teams operate and overcome challenges.

Finally, I would like to thank all of my friends and family for their necessary distractions and unconditional trust and support.

I hope you enjoy reading my thesis,

Ben van Rossum

Contents

List of Figures

List of Tables

Summary

Introduction

Today, mortgage originators are under a significant amount of pressure by regulators, shareholders, and supervisors to increase economic performance. Following the Basel IV accord, mortgage originators (Dutch banks: ING, ABN, AMRO, and Rabobank) have to hold more capital reserves to create a buffer for difficult financial times. Holding these extra capital reserves comes with the expense of sustaining current economic performance, which impacts the shareholders. The supervisors at financial institutions such as the AFM and the DNB are demanding more transparency to control the viability of the institutions and to prevent mistakes of the past. The Basel IV accord in particular is the driver of transferring mortgage loans to decrease capital reserves, because capital is not free. Unfortunately, securitisation transactions are complex, costly, and time consuming because of the many stakeholders involved. However, the introduction of blockchain and smart contract technology may make it possible to bundle forces in a distributed network and automate transaction and controlling steps to make this business process more efficient. Therefore, the objective of this research is:

To help financial service institutions identify and analyse the potential opportunities of blockchain technologies in the business process of securitising mortgages.

Two scientific methods are used: the information system (IS) framework of Hevner to gain insight into the behavioural-and design science that can be used in the redesign process of the securitisation business process. This framework has never been used for this purpose and will thus structure the creation of a new business process. The business process model notation (BPMN) is used to build a bridge between technical and non-technical decision makers and accelerate the implementation of blockchain-based technologies in the securitisation business process.

Methodology

To reach this objective, the researcher proposes a business process innovation through a technical information system framework, as previously mentioned. The framework aims to improve the effectiveness and efficiency of an organisation by using information systems (Hevner et al. 2004). Hevner's conceptual framework has been used in this paper to develop and evaluate the business process; furthermore, it is also used as a guideline throughout the thesis. Hevner's framework includes three elements: a knowledge base, the environment, and information system research. The knowledge base consists of a literature review and helps to elaborate the two main concepts: blockchain as the technology and securitisation as the business process. It also supports the answers to the first two subsidiary questions. The environment describes the surrounding factors within the problem such as people, organisations, and technology. Semi-structured interviews were conducted with experts of interested parties to determine these factors. These interviews enabled the researcher to gain knowledge of the securitisation business process and provided insight into the experts'

knowledge of blockchain. The experts also provided input regarding the three subsidiary questions (especially the third). The information system research was conducted in two phases: developing the model and evaluating the model. The first phase was performed using two analyses and one tool to develop a business process model. The first is an extensive stakeholder analysis and the second is a root cause analysis with the sub-causes of stakeholders, regulation, and technology to create a total picture of the environment. The BPMN was used to design the current process to make innovation opportunities clearly visible and also to create the business process based on blockchain. The second phase of the information system research framework is the evaluation phase. For this phase, expert discussions were conducted to introduce the built model. The experts assessed the model during these discussions, and their analyses were used to refine the final blockchain-based business process model.

Analysis
The interviews were fully recorded in order to re-analyze and transcribe their contents. The transcriptions can be found in the transcription document included by this thesis. These interviews are thoroughly analyzed by collecting the proper information to answer the first three sub-research questions. This analysis can be found in chapter four. Because the interviews were semi-structured a lot of additional information if found in the interviews. This information is also written down in this chapter under additional findings. After the analysis of the transcriptions, the information was coded and summarised in the last section of section four.

Business process model design
The modeling phase is described in chapter five. First, a stakeholder and root cause analysis were conducted based on the information obtained from the experts. In the stakeholder analysis, all stakeholders in the current process were analyzed to gain knowledge of their function and the impact the technology should have on their continuation. With this input and the knowledge gained in the literature review from blockchain, a stakeholder analysis with perspective on the future was the result. This stakeholder analysis determines which stakeholders will survive the technology transformation and which stakeholders need to emerge or improve their methods. After this analysis, the root causes analysis was executed. In this analysis, the three main causes that influences the model were identified: governance, stakeholders and technology. These analyses gave structure to the information gained from the interviews and brought the basis for developing a BPMN model for blockchain-based securitisation. Modeling in the BPMN is also conducted in two stages. First, the current model was recreated by a lack of an existing model, and in the last stage the blockchain-based model is created.

The model
In the executive summary, the simplified model of the blockchain-based securitisation process is depicted in Figure 1 or for an enlarged version Appendix E; in the thesis, this model consists out of five sub-processes modeled in BPMN. The first steps in the model are the same as the current process. The borrower is able to obtain a mortgage at the bank by passing several client and credit checks at different agencies. Because the application for a mortgage in itself is

already a very time-consuming process, this topic is outside the scope of this research. In the conclusion, a plain solution is given for this problem. However, the research began at the bank that had illiquid assets (mortgage portfolio) on its balance sheet. In the model, the bank will convert this mortgage portfolio into "secutokens " using a smart contract. These tokens can be sold on a token exchange or on an OTC (over the counter) basis to investors. These secutokens are valuated like a bond and have the same legal rights in this model. These secutokens can possibly be programmed in the contract with different risk profiles as residential mortgage-backed securities (RMBS). Then the investor is paid in a waterfall structure, the highest risk profile being paid the most but the last. However, the contract can also be programmed with equal valued tokens as assumed in this thesis. The investors are paid for the inherent risk, by interest and redemption payments of the borrowers. Payments of the borrowers must be to the smart contract to prevent a mortgage default. Subsequently, the smart contract is able to distribute the payments to the investors in possession of the secutokens.

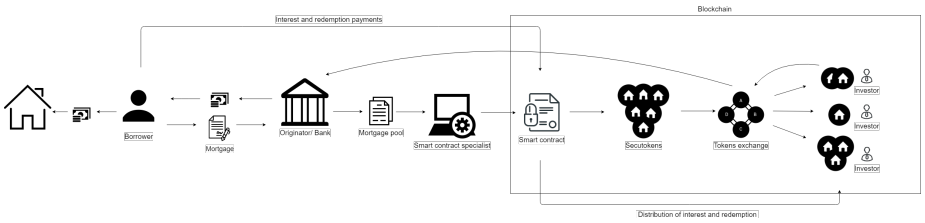


Figure 1: Simplified model

Validation
When the models were finished, the researcher entered into four discussions. Two discussions were conducted with experts that were interviewed before and two discussions were held with new experts to generate new insights. These expert discussions helped the researcher to refine his models and draw conclusions on the possible future model of securitisation in the R-MBS market. Internal validity is tested with counting repetitions of subjects in the interviews, in the end of chapter 6.

Conclusion
In the conclusion, answers are provided to the preset subsidiary questions and the primary research question. The researcher found that the securitisation process is currently a costly and slow process due to all of the involved stakeholders and administrative processes, many of which are executed manually. Transparency to supervisors and the liquidity problems of the products generated by securitisation are also burdensome characteristics of the process. Lastly, the most important challenge is the pressure of international regulations that threaten to hinder the economic performance of banks. This threat forces the bank to search for structural profitability improvements.

Tokenising mortgage portfolios using the blockchain could be a structural profitability improvement for the business process of securitising mortgages. Therefore, a new BPMN model of blockchain-based securitisation is created in this thesis in order to build a bridge between non-technical and technical deci-

sion makers. Furthermore, this thesis makes two additional scientific contributions to Hevner's IS research framework. The framework puts little emphasis on stakeholders and governance. When information systems based on Blockchain are researched these two elements are important to address. However, technology still hampers the implementation of blockchain in this business process. As examples of existing challenges, fiat currencies cannot be stored in a smart contract, and digital currency is still not an accepted payment method. Furthermore, many experts are discussing private and permissioned blockchains, but these networks refer to centralised networks with one or a few controlling parties. This detracts from the distributed idea of blockchain in which intermediaries or central parties are no longer necessary. Therefore, does this actually solve the problem for the main purpose? Or is solving problems with blockchain technology a temporary trend? Further research should consider these problems and should re-examine automating the securitisation process without blockchain, because many problems can be solved without it.

1 Introduction

1.1 Blockchain technology in the financial industry

Blockchain is a recent disruptive technology that is challenging many long-established industries. This emerging technology is able to automate business processes which have been labour intensive for many years. The history of blockchain began in 2009 when a person under the name Satoshi Nakamoto released the open-source software Bitcoin, which was the first cryptocurrency and worldwide payment system (Brito and Castillo 2013). This digital currency works in a distributed network that allows transactions take place peer-to-peer (directly between users) without an intermediary such as a bank(Nakamoto 2009). Blockchain is the underlying technology behind the Bitcoin concept, and it was invented to create a digital cash system on the internet without the need for a trusted authority or central server. This technology makes it possible to transfer monetary values over the internet. Before blockchain, it only was possible to transfer copies of files through this new functionality that is sometimes called Internet 2.0 (Perkins 2017) or the Internet of value (Aru 2018). Blockchain technology has inspired many industries to work toward solving certain problems (Popper 2016). It is potentially suitable in the ICT (information and communications technology) architecture of recording events, record management activities for medical or identity purposes, transaction processing, documenting provenance, food trace ability or even voting (Iansiti, Lakhani, and Mohamed 2017). In this thesis, the focus of study is the financial industry and how blockchain can affect the securitisation business process of mortgages. However, securitisation is not only performed with mortgages but is also used to fund other kind of loans such as car or business loans. Securitisation is also described in the following way:

"Securitisation is neologism for a method of financing whereby loan receivables or other cash flows are bundled into securities and sold to investors." (Simkovic 2013)

This process consists mainly of managing and recording transactions, which are executed by many additional expensive intermediaries. To optimise this business process to greater efficiency, blockchain technology could be a solution.

1.2 Problem statement

Pressure from regulators, shareholders and supervisors requires banks to increase their economic performance, and especially since the financial crisis in 2008, regulators have acted to increase financial stability. These steps toward stability have caused the regulatory capital requirements in the Basel Accords to become binding stipulations in order to increase economic performance, and the stipulations will further increase with the coming Basel IV Accord. In the current regulation of Basel III, there is a sensible link between risk and capital holdings. Consequently, institutions with a low-risk loan portfolio could hold less capital in reserve than institutions that deal with high-risk loan portfolios. However, Basel IV put an end to this sensible link between risk and capital

holdings with its capital floor initiative (Koch et al. 2017).This specification obliges institutions with low risk portfolios to hold an equivalent amount in reserve as that of institutions with high risk portfolios, which will increase the cost of capital for low-risk institutions to provide loans for mortgages and loans to strong, healthy businesses and households. This initiative will mainly affect the Dutch mortgage market with its historically proven low-risk profile (DNB 2016). The increase of this cost of capital as incongruous with the low risk of the loans that these institutions provide is likely to have negative consequences on the economic performance of the bank. Moreover, it will also elevate the cost of housing for ordinary families, slow down job creation and economic growth and potentially endanger financial stability.

Pressure also stems from the shareholders of banks. Market performance should result in sufficient returns to compensate investors with dividends for their inherent risk. However, the low interest rate environment limits banks' ability to generate sufficient returns to cover their cost of capital as required by Basel IV (PwC 2018b). Without structural profitability improvements, the new regulations will limit banks' ability to pay dividends in the future.

Supervision on banks has increased since the financial crisis. Supervisors are continually focused on the viability and sustainability of banks and their capacity to generate acceptable short- and long-term returns in both economically favourable and unfavourable times. To increase supervision, demand for transparency of banks' vulnerabilities and the implications of their exposure to company- and market-specific risks are needed.

These three sources of pressure are incentives for low-risk portfolio institutions (mortgage originators or banks) such as Rabobank, ABN AMRO and ING to transfer their low-risk assets (mortgages) from their balance sheet to decrease the cost of capital. Unfortunately, securitisation transactions to offload assets from balance sheets are currently expensive and very time consuming.

With the introduction of blockchain and its capability to tokenise assets using smart contracts, the archaic business process of offloading assets from balance sheets can be disrupted. Blockchain is able to increase transparency in the transaction records (Lotz and Websky 2017) with the result of reducing the required time for due diligence. Furthermore, the technology is able to the lower costs and duration's of transactions (Iansiti, Lakhani, and Mohamed 2017).

The idea of blockchain sounds promising in theory, but a lack of literature about this how the business process combines with blockchain technology has slowed down implementation. However, a re-designed and more efficient business process could be the start of this technology implementation in business.

1.2.1 Scientific knowledge gap

Blockchain technology is currently ready to securitise securities (Polymath 2018), but implementing blockchain technology in the current business processes for securitisation remains difficult. Research is needed to develop techniques for identifying, discovering, structuring, and analysing the relevant business processes so that they can be redesigned to adopt blockchain (Mendling et al. 2018). The information systems research framework developed by Hevner et al. structures this thesis. In this framework, design science and behavioural science come together; they are both needed to ensure the relevance and effectiveness of the information system research. This framework is particularly suitable for

the securitisation business process, because the design paradigm is used to redesign the information system in a way that blockchain can be adopted. In addition, the behavioural paradigm is used to meet the terms of all stakeholders and policy makers involved. This is the first time the business process of securitisation has been redesigned on the basis of the information system research framework. Interviews and discussions were used to gain insight into the behavioural and organisational side of the business process; thereafter, the BPMN is used to design a structured blockchain based securitisation business process. A securitisation blockchain-based BPMN model with these insights has never been created before, and is imperative to clarify this complex business process to less technical users, such as managers and policy makers. This could help these decision makers to understand the complex concepts behind the technical process and may increase the incentive to implement blockchain in the current business process. This research not only offers a redesign of the business process model, but also proves that the design and analysing tools are suitable for redesigning business processes based on blockchain technologies.

1.2.2 Research objective

For this study, the following research objective is formulated:

To help financial service institutions identify and analyse the potential opportunities of blockchain technologies in the business process of securitising mortgages.

Based on a qualitative analysis, the research offers recommendations for the securitisation business process and helps business decision makers understand the impact of blockchain technology. These recommendations can also help them to accelerate and manage other blockchain innovation projects.

1.2.3 Primary research question

The primary research question that logically follows from the problem statement and the scientific knowledge is as follows:

How can the business process of securitising mortgages be redesigned and is a public blockchain the appropriate technology when implemented in the ICT architecture?

Through the incentive of policy makers and new technologies, this question triggers research into how to modernise the securitisation business process using scientific frameworks, modelling, and analysis tools. Furthermore, it stimulates the research to the full potential of the technology used in the business process and put question marks behind the promises people make about blockchain.

1.3 Research approach

The subsidiary questions used to answer the primary research question and the reason for using the exploratory and design approach are presented in this section.

1.3.1 Subsidiary questions

Subsidiary questions are used to divide the primary research question in small manageable research questions:

1. What is the current status of the business process securitising mortgages and what opportunities could blockchain bring within the status quo?

   The first sub-question studies the current business process of the securitisation at Dutch banks and the incentives for changes to the process. This gives the researcher a broad knowledge about the current status of securitisation. Furthermore, it investigates the opportunities that could come from blockchain and whether these opportunities are suitable for the securitisation of mortgages.

2. What are financial service institutions' requirements for a new RMBS business process based on blockchain technology?

   This question investigates the requirements for financial service institutions to implement a blockchain-based MBS business process. This question is important because technology implementation depends not only on the technology itself, but also on the environment in which the technology operates (Hevner et al. 2004).

3. What would a new blockchain-based securitisation business process model look like?

   Once the opportunities and functions of blockchain are known, a securitisation business process is designed, and the technology environment is investigated . A proposal can be drafted for a new blockchain-based business process, and the IT technology can be designed in BPMN.

4. Do experts agree that the business process model created in this research is a viable option?

   Hevner's framework structures the design of this technology. The designing phase in Hevner's framework consists of two steps: development and evaluation. This sub-question focuses on the evaluation step, which is completed using discussions with subject-matter experts.

1.3.2 Exploratory approach

The first two subsidiary questions are answered with the exploratory approach. The use of the exploratory approach is to create a better understanding of the problem, as it investigates the research topic to varying depths. The answers to

these first two questions can change the direction of the research as a result of revelations from new data and new insights. This methodology is suitable for problems on topics with a lack of established theoretical grounding (Dudovskiy 2013).

Blockchain is a new disruptive technology that can provide sustainable competitive advantage in a variety of business processes, which accounts for the current wave of research in this subject. The securitisation business process is one that has the potential to be significantly improved by blockchain (Lotz and Websky 2017).

Semi-structured interviews are used to identify the blockchain opportunities for the securitisation business process. Exploratory research creates a strong groundwork for redesigning the business process model in a later stage of the study

1.3.3 Design approach

Findings of exploratory research are not typically used for decision making at a practical level (Dudovskiy 2013), which is why the design approach is used to answer the third question. In the design approach, the information systems research framework (Hevner et al. 2004) and BPMN are used to develop a robust design for the business process.

2 Literature review

In this section, the two main concepts of this research are analyzed: securitisation and blockchain technology. These concepts are thoroughly researched to gain the essential knowledge to build a BPMN model based on both of these concepts. The securitisation section consists of the fundamentals of securitisation, the working principle, the incentives, the risk it entails and the regulation it has to deal with. The blockchain section contains a broad perspective on the technology on the basis of what is currently known. The regulations that one must consider when implementing this technology is also elaborated.

2.1 Securitisation

This section of the literature review describes the working principle of securitisation. Securitisation is one of the business processes that make banks able to fund loans and mortgages. In this thesis the scope will be at the funding of mortgages, the products that came of the securitisation of mortgages are RMBS. Further in this chapter this will be elaborated. Securitisation comes together with different financial risks, which causes high regulatory restrictions after the financial sub-prime mortgage crisis in 2008. In this chapter, the necessary knowledge is gathered about securitisation to explore and to locate the issues and opportunities to the securitisation business process.

2.1.1 Fundamentals of securitisation

Mortgage securitisation has been attempted three times in U.S. history—during the 1880s, 1920s, and 2000s—and every time, it has collapsed. Most recently, competition between mortgage securitisers led to a race to the bottom in mortgage underwriting standards that ended the 2007-2008 financial crisis (Simkovic 2013). This race could be maintained because of a lack of regulation in the banking industry. Mortgages were granted to individuals with poor credit scores; this type of mortgage is called sub-prime. This type of banking is known as shadow banking and occurred in the mortgage industry on a large scale during this time. The growth in the use of securitisation for the selling of mortgage debt by financial institutions in America is depicted in Figure 2, in which a clear decline is shown after the financial crisis in 2007.

After the 2008 financial crisis, the share of sub-prime mortgage products declined due to market forces and a tightening of regulations. Today, the total American RMBS market is worth around $782 billion. America has the largest amount of RMBSs in the world, but this research focuses on the Dutch securitisation market as shown in Figure 3. The light blue segment of the pillars illustrates the amount of products that are comparable to RMBSs in the United States. The Dutch market is much smaller then the American one and thereby not as important. The securitisation market in Europe will recover with the rising interest rate set by the European Central Bank and the widening regulation (Drucker 2017) that is elaborated upon further later in this chapter.

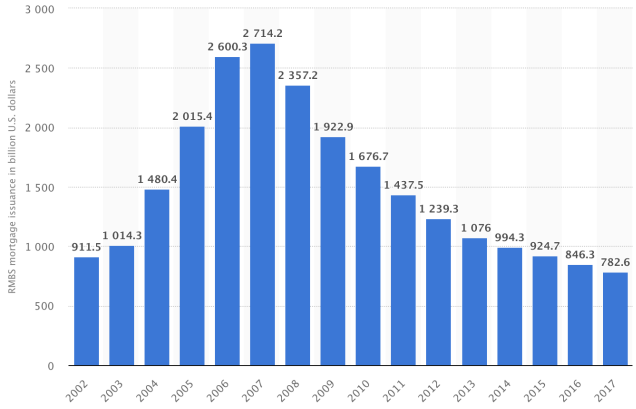


Figure 2: RMBS issuance Amerika, Source: Statica 2018

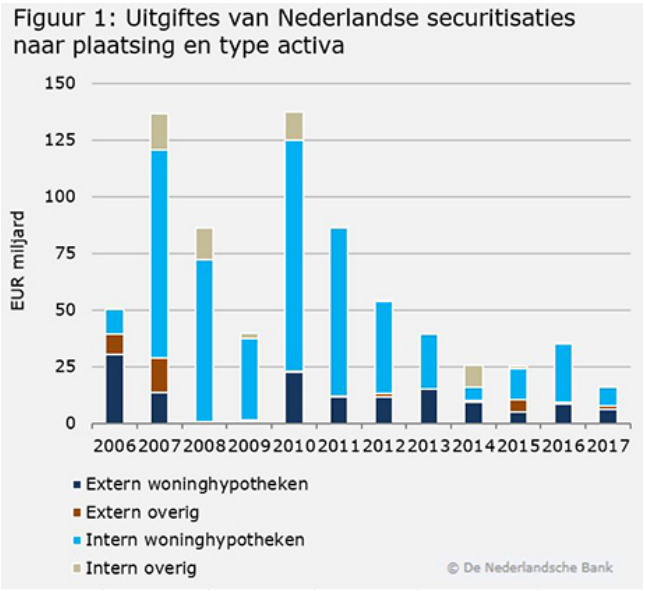


Figure 3: Dutch securitisations, Source: DNB 2018

2.1.2 Mortgage origination

Securitisation starts at the borrower that want to fund real estate, usually the borrower's house. Mortgages loans are loans specifically used to fund housing and are issued by "originators." Originators are commercial banks or financial institutions who offer loans to the public, like ING or Rabobank. In the first phase, the borrower searches the market for the best funding instrument in various commercial banks. When the borrower finds a commercial bank who wants to funds their house, a customer screening is performed. This screening is conducted to estimate the creditworthiness of the borrower. When the originator approves the creditworthiness of the customer, the originator accepts the piece of real estate as collateral for the loan. The collateral is used in case the

borrower defaults on their mortgage. If the borrower defaults on the loan by not paying the interest or redemption that was agreed upon, the originator sells the house to pay off the loan and the arrears. Most mortgages have a duration between 10 to 30 years. Over this time, the claim decreases when borrower pays off the mortgage redemption and interest. Originators are primarily divided in three parts: the service department, the controlling department and the monitoring department. The service department provides clients with advice and handles communication between the originator and client. The controlling department carries out the necessary checks on personal, income, and credit ability information. The monitoring department oversees and manages transfers of the mortgage. Before real estate is funded by the originator, the borrower must have a certain creditworthiness and trustworthiness to repay all their obligations. When all requirements are met, the mortgage can be funded. Then the notary is informed to make up a property deed and a mortgage deed, these deed guarantee the payment and property transfers. At last the Kadaster is informed to legally capture the property

2.1.3 Funding the mortgage marketplace

Loan originators raise funds for the issuance of mortgages in five ways (see Figure 4), to create a complete picture all the funding activities are discussed briefly, but securitisation plays the most significant role in this thesis. The process of raising funds is schematically depicted in Figure 5. The first method is to use the deposits of their clients. The second way to raise capital for funding mortgages is done by issuing bonds on the international market, with a fixed cash flow lower then the mortgage borrowers pay. The third way of raising money is to borrow money from another bank against the London Inter Bank Offer Rate (LIBOR - the interest rate at which banks borrow and lend money to each other). This rate is many times lower than the rate their money is lent. Apart from lending practices, the bank is able to raise capital through equity, either with common securities that are traded on the stock market but those are relatively expensive instruments that are mostly only bought for emergency balance repairs. The fifth and last way of funding is securitisation, in which an asset-backed debt is issued through securities.

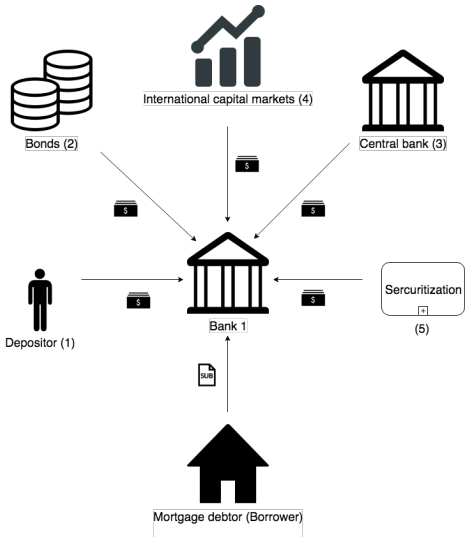


Figure 4: Mortgage funding

2.1.4 Working principle of mortgage securitisation

The pooling process of mortgages is called securitisation and is performed by the originator and additional institutions. The mortgages are assets of the originator and must be sold to an investor to obtain capital to continue funding mortgages. Between the originator and investor there is a special purpose vehicle (SPV), demonstrated in Figure 5. This SPV is created by the originator in collaboration with a financial attorney agency. This SPV buys the mortgages from the originator and takes over these assets and thereby the credit risk of the mortgages. In the SPV, the mortgages are pooled. This mortgage pool is then sliced into tranches. These tranches are then rated by a credit rating agency and get a risk profile. The notes out of these tranches can be sold on the market as RMBS.

The name collateral debt obligations (CDO) is widely used in the industry. These obligations are backed by different securities such as asset-backed securities (ABS) or Mortgage backed securities (MBS). Mortgage-backed securities are composed of two types: Residential mortgage-backed securities (RMBS) and commercial-backed securities (CMBS). The name is dependent on the asset that backs the security. Payments are managed by the SPV, mostly by a payment agent. The agent takes care of the interest and redemption payments from borrower to investor. This payout is usually once a month and also controlled by the SPV itself.

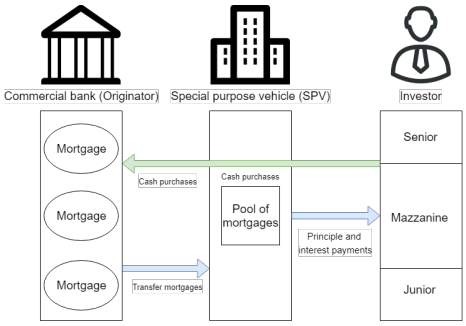


Figure 5: Securitisation

2.1.5 Creating collateral debt obligations

When commercial banks sell their mortgages to investment banks, there are two possible types of structuring: pass-through and collateralised debt obligations (CDOs). In the case of a pass-through, an investment bank sets up a trust fund. An intermediary (usually the investment bank itself) collects all of the monthly payments, and after deducting a fee, the payments are passed through to holders of the pass-through security. A CDO is a product consisting of a pool of debt obligations in which risk is spread in tranches. All of the tranches have different credit ratings from the moment of issue; these ratings are linked to annualised default rates (Coval, Jurek, and Stafford 2009).

These ratings range from AAA to D and are mostly granted by the three largest credit rating agencies (S&P Global, Fitch Ratings, and Moody's) as derived from their historical data. AAA is referred to as the senior level; middle ratings of AA-BB are called the mezzanine; and everything below B (and thus with the highest risk) is referred to as junior. When a credit rating decreases, the yield increases with the risk. Overall risk is a combination of liquidity risk (the limited frequency of trades) and credit risk (the default risk of the collateral). In this structure, the redemption and the interest payments are collected by the trustee and transferred to the investors according to the tranche's risk category . Thus, the senior CDOs are paid first, then the mezzanine CDOs, and finally the junior ones. The funds, like a waterfall, flow from top to bottom, so that the junior tranches are the least likely to receive payments. The process is displayed in Figure 6

This process of pooling mortgages can be clarified with a two-asset example. For instance, consider two identical mortgages, each with a probability of default (p_d). Both pay \$0 if they default and \$1 if they do not. Now, consider that these mortgages are pooled in a portfolio and divided into two tranches. These products then become collateral mortgage obligations (CMOs), because the collateral is a mortgage. Now the value of the underlying fund is \$2, and each tranche pays out \$1. The junior tranche will bear the first \$1 of loss in the portfolio: The junior tranche only pays \$1 if neither mortgage defaults and \$0 if one of them defaults. The senior tranche, however, still pays \$1 when one of the mortgages defaults. This senior tranche only defaults when both of the mortgages default. So, this tranche only bears losses when the junior tranche is exhausted (Coval, Jurek, and Stafford 2009).

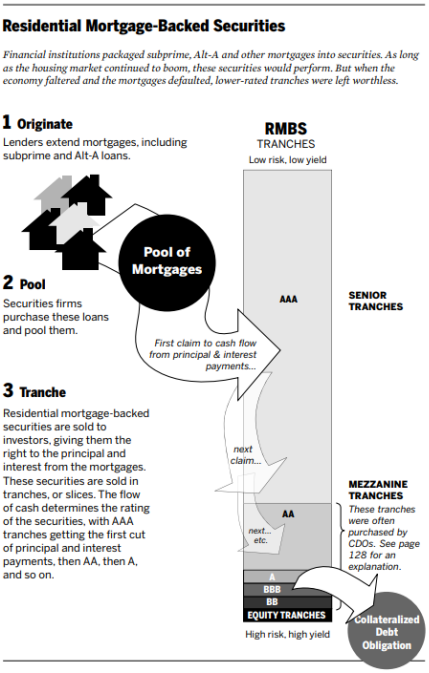


Figure 6: Creating CDO's, Source: Angelides et al. 2011

When the two bonds are imperfectly correlated, the senior tranche will still pay either \$1 or \$0, like the individual mortgages. However, it is less likely to default than either of the underlying mortgages. For example, if the two bonds have a 10% chance of default and defaults are uncorrelated, the senior tranche will only have a 1% chance of default (Coval, Jurek, and Stafford 2009). This process of pooling is able to transform high-risk investments into relatively safe financial products.

In the industry, this of course does not happen with two mortgages. Most often, packages with a value of \$1 billion are created. With a large number of mortgages combined in an underlying pool, tranches can end up with higher credit ratings than the average rating of the underlying pool of assets. For example, the two-mortgage example is expanded with an additional mortgage in the same capital structure. Now the first tranche defaults if any of the three mortgages default; the second tranche defaults when two or more mortgages default; and the senior tranche defaults when all three bonds default. If the mortgages have a 10% chance of default, the first tranche has a default chance of 27.1%, while the others have a 2.8% and 0.1% chance, respectively (Coval, Jurek, and Stafford 2009). With this pooling method, two thirds of the capital has less risk than the underlying mortgages.

This sounds like a positive result, but the junior tranches (referred to as junk), that remain become high-risk investment products. This makes them less attractive to investors. Another way to increase the value of those high-risk securities is to pool together junior tranches created in the first round of securitisation process. These products are called CMO^2. In the two-mortgage example, the junior tranche had a default probability of 19%. If this CMO is

pooled with another identical junior tranche, a senior tranche is created with a probability of default of 3.6% (Coval, Jurek, and Stafford 2009), which is considerably lower than the underlying mortgages. Those collateral debt obligations are products of tranches from other debt obligations. So this CMO^2 product is no longer backed by the mortgage or loan like a normal CMO, but is rather backed by a pool of collateral mortgage obligation tranches (Coval, Jurek, and Stafford 2009). CDO^2 has not been used in the Netherlands since the financial crisis of 2008 (A.CDO), and thus falls out of the scope of this research; however, it is discussed here for completeness.

2.1.6 The aim of securitisation

There are many reasons why commercial banks securitise their mortgages. The main motive of securitisation is reducing the funding costs of their financial products. This is done by creating an SPV that can lend with an AAA rating (Coval, Jurek, and Stafford 2009).Commercial banks (parent company) mostly have lower credit ratings than the SPV they create, because they only transfer assets to the SPV and not the corresponding liabilities to enhance credit quality. When the SPV's has a higher credit rating than the parent company, the SPV can borrow money at lower rates on the market from investors. This money is used to buy mortgages from commercial banks. For example, a commercial bank with a credit rating of BBB can create an SPV with a credit rating of AAA. The commercial bank must borrow its money at an interest rate of 2% when borrowed straight from market. The SPV, with its higher rating, can borrow at 1%. The spread between those percentages is the costs that banks save with securitisation

Another motive for securitisation is the transfer of credit risk. When, for instance, a bond defaults, the bank can be held liable. If a CMO defaults, the bank is not responsible because the investor accepted the risk beforehand. A CMO does not function like a bond but more like a stock. The investor can lose all of their money if the collateral value becomes worthless. This risk is thus transferred from the bank to the investor with securitisation.

The third reason for securitisation is off-balance sheet accounting. There are three reasons why it is profitable to keep assets off the balance sheet: First, some firms are limited in leverage due to legal, regulatory, or other reasons. By securitising their assets, they are able to remove assets from their balance sheet because it qualifies as a sale in accounting terms. However, they retain the earnings of the sold assets(Reis-Roy 1998). The second is liquidity. Future cash flows are simply not tradable. Securitisation transforms illiquid financial claims into tradable ones (Davidson 2008). The last one is admissibility. Future cash flows are uncertain and risky in contrast to acquiring new cash by securitisation. The issuer can transform future cash flows into direct cash, which can boost credit rating and earnings.

Before January 2018 , derivatives had no impact on the balance sheet, because future losses were uncertain. In 2014, the International Accounting Standards Board introduced a new accounting standard that derivatives must be included on the balance sheet (PwC 2017). Previously, excluding derivatives led to higher earnings and credit ratings. This is no longer an advantage.

2.1.7 Investor motives

RMBS investments are lucrative opportunities for investing institutions. They can be bought on the market and offer exposure to the mortgage market. This is far easier than the whole process of managing mortgage investments from beginning to end. Institutions purchasing such investment products are mostly insurance companies, investments banks, pensions, and hedge funds that are looking to diversify their portfolios in terms of risk and return. Because with a diversified portfolio, risk is minimised for the highest possible return (Reilly and Brown 2011)

RMBS also creates an opportunity for investors to invest in financial products that potentially earn a higher return than government bonds yet have the same credit rating. High risks are associated with these products, especially when the investors are not fully informed about the products. Credit risk is transferred from the originator to investor when buying RMBS. In the case of mortgage default, the investor loses money, or, when mortgage payments are delayed, delays in investor cash flow occur. This all depends on the credit rating of the investor's products. The AAA products receive payment first, the products with the lowest credit rating last. Risk is passed through from the beginning of the process; credit risk is high when customer creditworthiness is wrongly estimated before an agreement on the mortgage is made.

Interest-rate changes also pose a major risk on mortgage loans. The price of an MBS fluctuates in response to changes in interest rates, while the price of a floating-rate MBS is less exposed to interest-rate changes. Furthermore, interest-rate changes sometimes lead to prepayments of loans. This causes insufficient payments from the underlying borrowers, which can lead to decreasing yields or even bankruptcy for payment servicers. This is also one of the pains of servicer risk. Payment delays and reductions are mostly caused by servicer insolvency. This risk is reduced when a backup servicer is involved in the transaction (Sectors 2005.

Moral hazard is also a factor for the investor. Investors rely on managers and paying agents. These intermediaries are paid fees based on performance, so there is a temptation to manipulate the prices of financial products. Thus, conflicts of interests may arise between servicers and investors (Tavakoli 2005).

2.1.8 Risks in securitisation

Securities based on a mortgage as collateral are difficult to appraise and maintain because they are based on a mortgage loan. Mortgage loans have funding cycles of 30 years with fixed interest rates and principal payments. Risks for mortgage originators arise from fluctuating behaviour in the financial system. Originators try to match these cycles at the origination date of the mortgage loan. However, risks such as prepayment, slowdowns in home sales, and foreclosure ending in default are possible . These risks are related and influenced by international interest rates.

Prepayment risk is closely related to the interest rate. When a borrower has a fixed interest rate on a mortgage for the next 30 years, they have less incentive to prepay when the interest rate increases because they want to stick with the fixed interest rate. When the inverse occurs and interest rate decreases, mortgage borrowers begin to prepay the maximum amount to look for other,

cheaper mortgage loans. This is called *contraction risk* (Lemke, Lins, and Picard 2014).

Probability of default is also a huge risk that originators take by lending out money. In the paper by Kroot and Giouvris, probability of default and the loan-to-value (LTV) ratio are plotted against each other in Figure 7. This empirical study indicates that there is a relationship between probability of default and the LTV ratio. The LTV ratio is indeed a risk driver of the probability of default. When the LTV increases—in other words, when the borrowed portion gets larger in relation to the value of the asset—the possibility of default also increases.

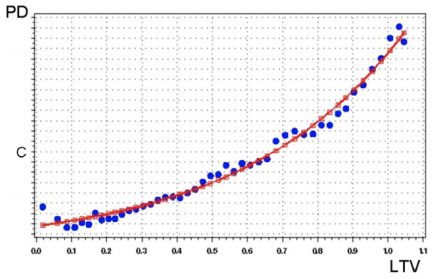


Figure 7: Probability of default and the loan-to-value ratio. Source:Kroot and Giouvris 2016

Investors acquire these securities or MBSs in accordance with a certain level of yield. These yields are paid based of the conditional payment rate (CPR). The CPR is the proportion of the mortgage pool redemption that is assumed to be paid off ahead of time each period. The two previously discussed factors have a significant impact on the calculation of the CPR, and other factors—such as historical prepayment probability, age of mortgage, burnout multiplier (number of arrears), and future economic outlook (economic and unemployment growth)—also play a role. However, according to Kroot and Giouvris, these additional factors have a relatively small influence in the calculation. Nevertheless, with all those factors, the CPR is an intensive calculation of risk used when valuing an MBS.

But valuing an MBS is not the only challenge for originators. There are risks of refinancing caused by the maturity period of a mortgage (30 years), which does not match the average refinancing cycle of the originator of around 5–7 years. Furthermore, transparency creates certain risks, since there are many intermediaries involved in the process of securitisation. These intermediaries ask for high fees for their services. These high fees attract external parties, which increases the interdependence among a growing group of actors in the system. The failure of one actor can quickly create systematic risk, as happened in the mortgage financial crisis in 2008.

Refinancing risk is created by the difference in cash flows in and cash flows out. When funding a mortgage, the originator receives interest and redemption in returns. This performs on a basis of a 10- to 30-year contract period, sometimes with a fixed interest rate over the entire contract period. But these returns are different from the originator's funding, which has a funding cycle of 5–7 years. Originators solve this problem with short-term debt papers, which

lead to constant refinancing needs (Hellwig and Samuels 2008).When moving risk and returns over time, originators must create a buffer for days when the availability of funds for refinancing is shorted. If they must use a fire sale for long-term loans, it will have a negative effect on the underlying asset prices, which directly impacts the whole industry that invests in the same products (Hellwig and Samuels 2008).

The poor transparency of banking activities was one of the causes of the financial crisis in 2008. Structured financial products like MBSs and CDOs were blamed for being too risky. Investors could not foresee the risk level of the products, because they were too complicated to understand. Much research after the financial crisis concluded that a lack of transparency increases the probability of a crisis. Gil Mehrez and Daniel Kaufman concluded the same in their empirical research based on the data of 56 countries: *' the lack of transparency increases the probability of a crisis following financial liberalization (Mehrez and Kaufmann 2000), p.2.'* In addition, Pagano and Volpin concluded that investors did not have the skills to process the amounts of data and had to rely on reports of credit rating agencies, which were often not as specific or prudential as they should have been (Pagano and Volpin 2012).

The last risk to mention is also sometimes called *skin in the game*. This concept arose prior to the financial crisis. Mortgage originators sold more mortgages to 'Ninja' (no income, no job or assets) clients when planning to sell them through securitisation than when planning to hold them (Demiroglu and James 2012).Other parties also had skin in the game through these funding practices. In order to set up a securitisation transaction with an SPV, multiple actors were involved that gained millions of dollars with massive fees. In interviews, experts indicated that a securitisation transaction of $1 billion could cost $1 million in annual fees, or up to 1% of the whole mortgage portfolio. This was, therefore, an incentive to sell mortgages to Ninja clients when all the better-rated customers already had a mortgage.

2.1.9 Securitisation Regulations

All the risks discussed above concerning securitisation were contributing factors to the financial crisis in 2008. To control these risks, the Basel banking regulations were developed by the Bank for International Settlements in order to promote stability in the international financial system. This set of regulations was agreed to by the G20 and was followed by the European Union's Capital Requirements Directive IV.

Basel I, II, III and IV

The Basel Capital Accord is a set of regulations for the banking industry designed to promote financial stability. Three versions of the accord have been accepted: Basel I, Basel II, and Basel III. The final reforms of Basel IV have not been agreed upon by all parties, and therefore the expected impact of the new regulations cannot yet be fully articulated (Koch et al. 2017).

Basel I

In 1998, the Basel Committee of Banking Supervision (BCBS) published a set of minimum capital requirements for banks. This accord is also known as the 1998 Basel accord. The accord focuses mainly on the credit risk of banks and the applicable risk weighting of assets. Assets of banks were classified and categorised into four categories according to their credit risk. Their risk weights

were expressed as percentages:

1. 0% for cash, bullion, and home-country bonds or U.S. treasuries
2. 20% for securities with the highest AAA rating, such as mortgage-backed securities or RMBSs.
3. 50% for municipal revenue bonds or residential mortgages
4. 100% for corporate bonds and bonds with no rating

Furthermore, banks were required to hold in reserves at least 8% of their capital risk weighted assets (RWA). To calculate necessary bank reserves, the following formula is used:

$$\text{RWA} = \text{Risk weight} * \text{value of assets}$$

$$\text{Capital required} = 8\% * \text{RWA}$$

As an example, consider a bank that owns capital of $100 million of AAA-rated RMBSs. The bank is required to set aside 2% of $100 million multiplied by 8%, which means that $1.6 million in capital is required.

The RWA of this capital is based on the credit risk of the asset. The RWA includes the probability of default, potential loss from reselling the property if the mortgage defaults, and the exposure to defaults. Under the Basel accord, claims secured by residential property (the most important group in this thesis) have a risk weight of 35% (BIS n.d.). Nevertheless, banks were still using their own models to calculate the risk and the required capital up until the financial crisis of 2008. Basel II intensified supervision of those calculations.

Basel II

Basel II intensified the supervision of banks in 2008, but unfortunately the implementation of Basel II could not prevent the financial crisis. In fact, Basel I was one of the triggers of the financial crisis: because it set a required capital standard without matching rules, banks intensified their securitisation of loans, which drove the unwinding in the sub-prime market. A further weakness of Basel I was that the regulation designers did not take into account the quality (risk weights) of counterparties (mortgage owners or large companies such as Apple or Microsoft). This was corrected in the Basel II accord. The Basel committee also required stronger supervision of market and operational risk. Basel II made it mandatory to set aside sufficient capital to cover any losses of not only credit risk (included in Basel I) but also market risk and operational risk (Basel II). So, market and operational risk must be taken into account when calculating the remaining 8% required capital, which is also known as Pillar 1 in the Basel II accord. In addition, reporting obligations to national regulators were increased to ensure that banks were holding on to the minimum capital. This Pillar 2 was a sort of enforcement mechanism of Pillar 1. Finally, Pillar 3 focusses on the disclosure of risk and measures. Banks can use their own models in Basel II, but Pillar 3 caused much more transparency than intended in Basel I. Basel II is accompanied by many complex formulas and regulations; therefore, some countries have implemented basic versions of this accord. Unfortunately, in the United States and Europe, it took banks several years to meet the terms of Basel II.

Basel III

Basel III is yet another improvement in the banking regulatory framework based on Basel I and Basel II. Basel III does not focus solely on the enhancement of durability under financial stress, risk management, and banking transparency; it also foster greater resilience at the individual bank level to reduce the risks of wide financial shocks. The accord sharpened the capital requirements from the earlier two Basel accords by dividing the regulatory capital into Tier 1 and Tier 2 classifications. Tier 1 contains shareholder equity and retained earnings, and Tier 2 contains revaluation reserves, hybrid capital instruments and subordinated term debt, general loan-loss reserves, and undisclosed reserves with a maturity of at least five years. The decided risk weights on assets were unchanged from Basel II, but the required capital ratios were increased. The capital required by Basel III for Tier 1 is increased from 4% to 4.5%, and the minimum for Tier 2 from 4% to 6%. The overall regulatory capital was left unchanged at 8%. In addition, countercyclical measures were introduced to prevent banks from cyclical changes in their balance sheet. During economic upturns, banks must set aside additional capital in order to maintain these capital requirements in times of credit contraction. This is also called the *bucketing method*, by which banks were categorised according to their size, complexity, and importance. Banks with a greater systemic importance were subjected to higher capital requirements. Finally, the leverage and liquidity ratios were included. These ratios are used to prevent banks from large credit positions and ensure a buffer of credit liquidity to satisfy banks' short-term obligations during periods of financial stress.

Basel IV

In January 2016, the BCBS revised ITS calculations for RWAs and updated the market risk framework. These revisions are known as Basel IV. The Basel IV accord placed further restrictions on low-risk credit positions such as mortgages. In the Basel III accord, financial institutions had fewer capital restrictions on low-risk loans than on high-risk loans. The proposed Basel IV capital floor initiative would put an end to this sensible link between risk and capital holdings (PWC 2017).This means that, under Basel IV, financial institutions with a low-risk portfolio would be required to have the same reserves as financial institutions with a high-risk portfolio. Low-risk portfolios contain mostly low-risk associated capital, such as treasury bonds, mortgages, and loans from strong and healthy businesses. This means that the cost of capital associated with these loans would increase and would not reflect the low risk that they provide for their customers. This could lead to negative consequences for the cost of housing and slow down growth and job creation. This Basel accord could have a major impact on the Dutch mortgage market, given the already low default rate and the high number of Nationale hypotheek garantie (NHG) mortgages. This safe mortgage environment would be charged with the extra cost of capital and would make it more difficult, especially for people with high LTV ratios (new home owners) to originate a mortgage. The RWA of low-risk assets is expected to increase by a factor of 2.5 and would thus lead to serious disadvantages for newcomers to the mortgage market.

EU Capital Requirements Directives IV (CRD)

Basel II and Basel III were set up to give banks a stronger capital position and liquidity buffers in order to be able to bear times of cash shortages. This regulation was followed the European Union (EU) Capital Requirements Directives IV

(CRD), a supervisory framework covering the whole EU. The most important aspects of this framework are the risk weighted assets, countercyclical buffers, and leverage and liquidity coverage ratios. All these aspects had been previously discussed, but the CRD framework is crucial in making banks comply with the Basel regulations.

Solvency II

The Solvency II Directive a European law for insurance companies. This set of regulations mainly concerns the amount of capital European insurance companies must hold to reduce their risk of insolvency. Because this set of regulations is focused on insurance companies, it is not out of the scope of this research. This law is the reason for regulatory arbitrage between commercial banks and insurance companies. In this law, the link between risk and capital reserves still plays a role, and no standardised output floor is introduced. This results in a lower cost for low risk investments, and makes it lucrative to fund mortgages with the stagnated money of insurers. The money of insurance companies is in fact 'cheaper' then originators money.

Wet financieel toezicht (WFT)

Supervision of the financial institutions in the Netherlands is regulated by the *Wet financieel toezicht* (WFT), or law on financial supervision. The actors involved in the WFT are De Nederlandse Bank (DNB) and the *Autoriteit Financiele Markten* (AFM). The DNB provides supervision on the prudential aspect, whereas the AFM is the authority for behavioural supervision. The WFT has three main purposes, of which the first two are primarily the responsibility of the DNB while the third is the responsibility of the AFM. The main objectives are:

1. Maintaining the stability of the financial system and thereby creating efficient markets in the Netherlands

2. Implementing EU regulation to preserve the solidity of financial institutions

3. Securing codes of conduct of good behaviour and transparency in order to protect the customer in financial markets

The WFT is designed and dedicated to financial services and financial products. Services include the offering, mediating, or advising on financial products. Financial products include banking products, investment products, insurance, and combined products such as RMBSs. According to the WFT, financial institutions must comply with the following principles:

1. **Reliability**. Financial institutions must recruit reliable staff. Responsible managers must be approved by the AFM to lead financial institutions, and all other employees who are responsible for client contact must be reliable. They cannot have any criminal record or have been responsible for financial failures.

2. **Expertise**. To comply with the WFT, financial institutions must have sufficient employees with the right financial professionalism and expertise. This applies to managers and employees with client contact and must be demonstrated with academic degrees or through internal education programs.

3. **Financial security**. This only applies to mediators in insurance companies. They must have a professional liability insurance (BAV in Dutch) to carry out their profession.

4. **Business management**. The business management of financial institutions must be adequate and honest; the administration system within an organisation must be adequate and controlled by internal audit. The administration of customer files, incident recording, complaints, and personal information are important aspects of this management. In addition, having incident scenarios for any possible mistake is important to honest business management.

5. **Duty of care**. Institutions must provide honest advice to customers. The starting point for the financial institution is to understand its clients, which is known as the know-your-customer principle. When dealing with products for professional investors like insurance and pension companies, advice on asset-backed securities must be in accordance with three steps: First, the financial servicer must create a customer profile. Next, the advice of the financial institution must verifiably fit the client on the basis of a relevant customer dossier. Finally, all aspects of the advice must be clear to the customer. Another important requirement of the duty of care is that the financial institution must check the credit status of its customer in order to evaluate if offering the financial product is a responsible action.

6. **Transparency**. Financial institutions must be transparent about financial products. The information provided must be relevant to judging the concerned financial product. The information must be correct, understandable, and not misleading. This information duty is included in the WFT to reduce the knowledge disadvantage of the customer in comparison to the financial institution. This financial information is mostly provided in the financial leaflet or prospectus. Furthermore, the financial institution has a continuous duty to inform when using long-term contracts.

It is not permitted for financial institutions to operate without a WFT permit. The permit is granted by the AFM while maintaining quality control over reliability, expertise, financial security, and business management. When financial institutions do not comply with these quality characteristics, WFT permits can be revoked and the financial institution's activities can be discontinued.

2.2 Blockchain Technology

In this section, the concept of blockchain technology is explained. First there is a brief introduction to the technology, and then the working principle is discussed, in addition to some variations in the technology. Subsequently, the benefits and limitations are discussed. A literature review of the applications such as smart contracting and tokenizing is also reviewed. The section ends with a preliminary conclusion on the technology used in Securitisation.

2.2.1 Fundamentals of blockchain technology

Applying blockchain technology in a business process is difficult when the fundamentals are not clear. This section therefore explicates the fundamental aspects

of blockchain technology. It is important to understand the principles of the technology when making determinations about whether to integrate the technology into the business process of Securitisation. The blockchain technology will be explained on the basis of a bitcoin transaction because this was the first blockchain application developed by Satoshi Nakamoto. This keeps the complexity of the technology low but still contains enough information to improve the business process of Securitisation.

Bitcoin

Bitcoin is the first blockchain-based application developed by Satoshi Nakamoto. In 2008, the white-paper of bitcoin was released and blockchain technology was created. In this white-paper, the working principles of the cryptocurrency bitcoin are explained. Bitcoin is online money that can be sent directly between peers. This happens in a peer to peer network on the internet without using an intermediary like a financial institution. This becomes possible by using blockchain technology. For a full explanation of the blockchain technology behind bitcoin, the white-paper of Satoshi Nakamoto is a good resource (Nakamoto 2008)

Sathosi Nakomoto was searching for the solution of the "double spending problem" on the internet. By finding a solution to this problem, it was possible to send money directly between persons without using a bank that tracks the records. For example, when an email is sent, the sender holds a copy on his computer. This principle does not work with money. The sender could spend his money twice by sending it again to another person. Blockchain technology eliminates this "double spending problem" (Nakamoto 2008).This problem is now solved by financial institutions that hold ledgers that keep track of all transactions. Nakamoto suggests that this system must be based on cryptography instead of trust. In the bitcoin solution, Nakamoto refers to a solution were the ledger of transactions is distributed in a distributed network (see Figure 8) and accommodated by all the nodes (participants). All the nodes work together to verify and compute all the transactions. In a distributed network, all nodes are in connection with each other. The dependency of other nodes is small in comparison to a centralised and decentralised network. In a distributed network, all nodes continue to function even if some nodes disappear (Buterin 2017).

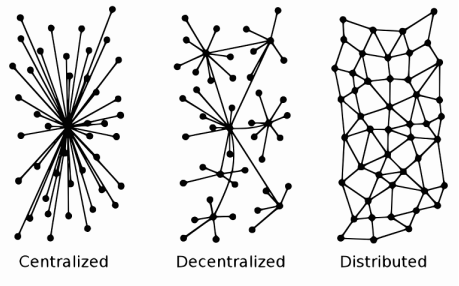


Figure 8: Different networks, Source:Buterin 2017

Public and private key

The transactions between the peers remain secure because nodes make use of asymmetric encryption by generating public and private keys. The public key is a string of random digits a node holds; this public key is used to identify the peer that has the rights to receive the transactional content. With a private key, the future owner can sign the transaction from the peer that created that transaction. Because the public and the private key are linked the second peer that receives the transaction, the public key and the transaction signature can be used to verify that the transaction is authorised by the person holding the private key. Theft can be committed when a peer's private key is known, so for safety reasons the private key must be kept secret. This is maintained with a hash function. This is the transaction data from the previous block with the public key of the receiver. This creates a signature of the transaction. This signature can be signed by the private key of the sender to prove that this transaction originates from the right source. This principle is clarified in Figure 9.

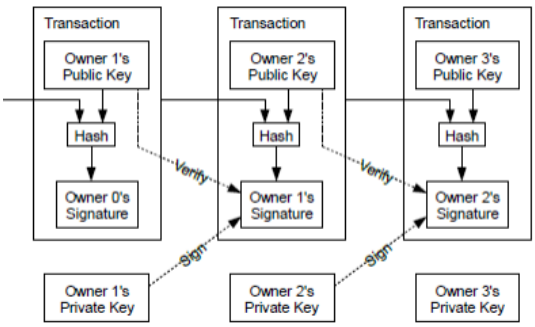


Figure 9: Transactions, Source: Nakamoto 2008

The hash function

The hash function is the central security concept of the blockchain. This function transforms all kinds of data into a string of random digits that has a predetermined length. The output of the hash is always the same if one provides the same input, but it is almost impossible to derive the input of a hash function from the output. This is also called one-way cryptography. The output of the hash is the transaction signature and because the public and private key match the signature, it can be verified and signed by those keys. Hashing has two functions in the bitcoin architecture. One is to turn transaction data and the public key always into the same generated output. The second is that this output keeps the input invisible. All of the data in the block, which includes the hash from the previous block, passes through a hash function to produce a new hash value. Verifying transactions is performed with mining or calculating blocks. When a block is mined, the miners find the right nonce; these nonces are created through repeated hashing of data (a specific number linked to the block). This calculation of the nonce value is called mining. The nonce is the number miners are searching for to find the right hash with the predefined zeros. The right nonce leads to the right hash output. With this legal hash output, the block is signed and can be chained into the ledger. This calculation refers to the process of proof-of-work (PoW) (Nakamoto 2008). If a hash does not begin

with the predefined zeros, the block is not signed. When the data in one of the blocks in the blockchain is modified, for example for a hacker, the Hash function of the block will be changed. This is because all of the blocks share data from the blocks behind them, and the hash value of all the subsequent blocks will change as well. Through all the changes in hash functions, all the blocks must be remined.

This process does not guarantee the security of the blockchain. The principle that the blockchain is copied in all the nodes in the distributed network causes the ability for the nodes to compare the data of the blockchains to one another. For example, if a blockchain is hacked in one node by changing transaction data (creating a double spending problem), the hacker has to validate all the blocks until the end of the chain. The problem is that when the hacker is able to validate all of the blocks on one node, this data will be different from all the other nodes in the network. Nodes in the distributed network always work together, and the nodes will notice the difference in the hacked node and will not accept the hacked blockchain.

This basic explanation of blockchain contains only the main principles of the first blockchain application Bitcoin. The primary purpose of this thesis is not to explain the technical details of this principle. Further technical details of the Bitcoin blockchain can be found in the white paper of Sathosi Nakamoto. After he released his idea to the world, many people noticed the usefulness of blockchain and began to develop the technology. Vialik Buterin was the first person to implement the idea of Nick Szabo in the blockchain. This led to the use of blockchain in several sectors other than the financial industry. The next section explains this more in detail.

2.2.2 Smart contracting

As previously mentioned, blockchain applications are mainly used for cryptocurrencies or digital payment methods. However, with the introduction of smart contracts in 1994 by Nick Szabo and later applications of blockchain by the founder of Ethereum, Vitalik Buterin, blockchain became more useful in other sectors as well (D. Tapscott and A. Tapscott 2016). Smart contracts are applications programmed on blockchain to help exchange money, property, shares, or anything of value in a transparent and conflict-free way while avoiding the services of a middleman (Christidis and Devetsikiotis 2016). This is done by converting the contract into computer code and storing it in the network. The contract is immutable after it is created, and it behaves exactly as programmed so that agreements cannot be changed (DutchBlockchainCoalition 2017). A smart contract is able to fulfill the rights, obligations, and possible outcomes between two parties agreed upon in advanced. These contracts can be used for a broad number of business uses, such as unlocking the doors of Airbnb houses only after payment is received (D. Tapscott and A. Tapscott 2016)) or paying for sent goods only when they have arrived (Christidis and Devetsikiotis 2016). Smart contracting is not possible on every blockchain, while the best known blockchains for smart contracting are Ethereum, Neo, Hyperledger, and EOS.

To clarify the working principle of a smart contract, the example given by Tapscott is visualised in a small flow diagram in Figure 10. Suppose person 1 is renting a holiday apartment to person 2 through Airbnb. You can rent this apartment through a blockchain application by paying with a cryptocurrency,

labelled in the figure as ether (cryptocurrency Ethereum). To enter into the contract, person 1 has to store the amount of ether in the contract and person 2 provides the digital entry key of the apartment (DutchBlockchainCoalition 2017). The traded goods are stored and securely coded cryptographically into the contract when they both approve the contract and the conditions are met. The contract then releases the traded goods to the persons that signs the contract. When the digital key does not arrive before the agreed date, the smart contract releases the refund automatically through the if-then statement in the contract itself. The transparency of the blockchain creates hundreds of witnesses, which increases the faultless delivery. If person 2 gives the key to person 1, they are sure to be paid and person 1 is sure that he is not being scammed. The smart contract automatically cancels after a certain time, and the code cannot be interfered with by intermediaries or participating parties.

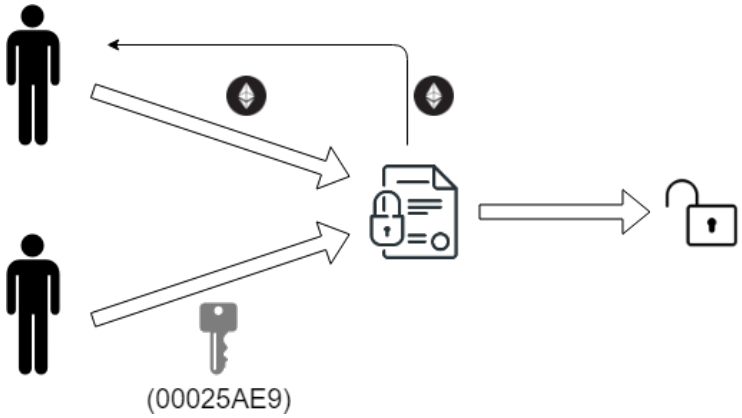


Figure 10: Smart contract

Oracles

To determine if the contract fulfils certain conditions, data input from outside the blockchain is necessary. Take the example that was previously mentioned: executing the smart-contract when the goods are delivered. In this case, data input is necessary to confirm that the goods are actually delivered because a blockchain is 'deaf and blind' and is therefore unable to obtain this information itself (DutchBlockchainCoalition 2017).This responsibility is thus assumed by the oracles. Oracles send the data input to the blockchain that will lead to the execution of the smart contracts. The parties involved in the contract have to trust the data input of the oracle, but are unable to verify if this information is true. If parties decide not to trust one oracle, it is a possibility to have different sources vote. However, the role of an oracle resembles the role of a third party, like a notary or a mediator, that signs a contract for legal purposes, although an oracle does not have to understand the utility of the information it sends and is therefore less susceptible to fraud (DutchBlockchainCoalition 2017).

Tokenisation
To understand what tokenisation is, it is important to understand the difference between a currency (coin) and a token. A coin is a digital cryptocurrency that has its own standalone blockchain such as bitcoin, which uses the bitcoin blockchain, and ether which is the currency of the blockchain Ethereum. A token can refer to any cryptocurrency that is built on an existing blockchain such as OmiseGo (OMG) or VeChain (VEN). These two coins use the Ethereum blockchain as the underlying technology. A coin is therefore the 'native currency' of a blockchain and a token can be viewed as a different issued asset of a particular blockchain. This is the cause of the 750 blockchains with native currencies and the more than 1000 tokens on the market. The most utilised blockchain for creating tokens is Ethereum with the ERC20 protocol. This protocol can be manually customised with programmed conditions to which the asset (token) must comply. Therefore, the tokens' value is related to the smart contract and a currency's value is related to its own blockchain (Rikken 2018).

Through the development of blockchain and its smart contracts, every sector could have their own blockchain application. This could possibly be the reason why thousands of blockchains each with its own features currently exists, and all of these cryptocurrecies seem to be basically the same in terms of technology. The largest differences between the currencies are in the consensus mechanisms, which will be discussed in the next section.

2.2.3 Consensus mechanisms

The information of a distributed network is stored on all network nodes, rather than in a central location as a central database. Thus, a distributed ledger is not controlled by a central body but rather by all the nodes in the network. The key operation of the consensus mechanism is to ensure that all of the nodes in the distributed network collectively agree on the content of the ledger. The principle of the consensus mechanism is to verify whether the information that is added to the ledger is valid; if so, then the network is in consensus (Castor 2017). This prevent malicious nodes to execute cyber crime and *the double spending problem* for every block added to the chain. A number of consensus mechanisms have emerged in blockchain technology, each with their own strengths and weaknesses, but they all serve the same principle. The main difference between the different consensus mechanisms is the way they delegate and reward the verification process of transactions. In the next section, the most widely used consensus mechanisms are briefly described without going into too much technical detail.

Proof of work
Proof of work (PoW) is the consensus mechanism operating in the blockchain application Bitcoin and is therefore the most well known. The first concept did not come from Bitcoin's developers but from Cynthia Dwork and Moni Noar in 1993. The term *'proof of work'* emerged when Markus Jakobson released his work six years later. Proof of work is based on the process of mining. The concept of mining is the process of calculating the nonce of the mempool that corresponds with the hash starting with the pre-fixed number of zeros. This is referred to as *solving the mathematical puzzle*. This mempool is an unveri-

fied pool of transactions; when verified, it becomes a *block*. If the right hash is found, the transactions in the mempool are verified, and the block is added to the chain (Khatwani 2018).). The first miner to solve this mathematical puzzle is rewarded with monetary compensation and a transaction fee, i.e., an amount of bitcoin. This reward will encourage miners to perform the mathematical calculations, which require a lot of CPU power and energy. This encourages the miners to work in pools, thereby centralising the blockchain instead of decentralising it. The mathematical puzzle is asymmetric (meaning it is difficult for the miners to solve the puzzle but it is easy to verify), which makes it easy for the nodes to verify blocks quickly and keep working on the longest chain, so they create more consensus on the data in the chain. This chain is the one that is accepted by all the nodes and considered to be true in the system. Bitcoin's developer Satoshi Nakamoto wrote in a white paper on Bitcoin that the only way to overpower the Bitcoin network or conduct dishonest work (e.g., a cyber attack) is to use up more than 50% of the computational power of the network. The PoW protocol is used to prevent any entity from gaining majority control over the network and thus guarantees trust and security. Bitcoin is not the only cryptocurrency using the PoW mechanism; Litecoin, Ethereum and Dogecoin are also using it.

Proof of stake
In 2011, the idea of the proof of stake (PoS) consensus mechanism was posted to a blog by a member named QuantumMechanic. This member offered a different solution from proof of work. Now, several cryptocurrencies are using this mechanism, such as Nave Coin, Neo, and Lisk. Ethereum co-founder Vitalik Buterin has also committed to bringing this mechanism to the Ethereum network. In the PoW mechanism, miners compete with each other with their amount of computational power, which leads to an enormous waste of energy. With the PoS mechanism, nodes are randomly chosen to validate the next mempool. An important difference between the two mechanisms is that PoW works with miners and PoS with validators; these validators do not mine blocks but rather mint them. To become a validator in the PoS network, the node must deposit an amount of coins into the network as stake. The size of this stake determines the validator's chances of being chosen to mint the next block. The incentives for the validators are the transaction fees within the block. This process is based on linear calculation (e.g., a 10 times higher stake means 10 times higher chance). This seems to be unfair because the rich will likely get richer in this process. However, it seems to be fairer than PoW, because here the rich can use the calculation of economies of scale; energy for computational power gets cheaper as more is purchased. Trust within the network is built by stripping miners of their stake if their nodes approve fraudulent transactions. This only applies when the stake is higher than the reward they receive when the mempool is minted.

Delegated proof of stake
Delegated proof of stake (DPoS) is a derivative of PoS founded by Dan Larimer as the consensus mechanism of BitShares. This mechanism is also referred to as the cryptographic version of democracy (Zheng et al. 2017) and is applied in numerous blockchain platforms such as Lisk, Steem, and EOS. The major difference between PoS and DPoS relates to people with high stakes. The stake a

node holds, weighs in the election process of delegates. These delegates are able to validate transactions. When delegates do not act properly, the voting system automatically replaces these authorised nodes. There are strong monetary incentives for delegates to remain in their position, they will keep the community satisfied by validating in an honest and efficient manner. Furthermore, this mechanism sets up a structure in which minters can collaboratively validate blocks, which makes the process more efficient and minimises transaction times in comparison with the PoS mechanism. Critics claim that an authorised group of delegates makes the system too centralised, because the group gains power that can be exploited.

Proof of capacity
Proof of capacity (PoC) is a relatively new consensus mechanism formulated by Stefan Dziembowski et al. in a 2015 paper Dziembowski et al. 2015. It is used by the blockchain applications Burstcoin and has many similarities with proof of work. This consensus mechanism involves two mechanisms: *plotting the hard drive* and regular mining. PoC uses Shabal hashing instead of the SHA-256 hashing used in PoW. This hashing algorithm is very slow and difficult to calculate, which is why it is pre-computed in the hard drive. In this process, known as plotting the hard drive, a plot file is created. In this plot file, nonces are stored through repeated hashing data. The more hard-drive space allocated to this plot file, the more nonces can be stored. One nonce contains 8,192 hashes, which are organised in pairs, or scoops, that are assigned a number from 0 to 4,095. During the mining, a scoop number from 0 to 4,095 is calculated. If, for example the scope number 32, its calculated plot file will look for every nonce in the hard drive to scoop number 32 and will derive a *deadline* (or amount of time, i.e., 15 seconds). After calculating all of the deadlines, the mechanism uses the shortest deadline. This number of seconds is the elapsed time since the last block was created before a new block can be forged. The node with the fastest elapse time receives the block reward. The advantage of this system is that it uses less energy than other mechanisms because all of the information is pre-computed in the hard drive but leads to other challenges, i.e., the need for the largest hard drive.

Practical Byzantine fault tolerance
The concept of practical Byzantine fault tolerance (pBFT) is published in a 1999 paper by Miguel Castro and Barbra Liskov. It is an optimisation of the original BFT consensus mechanism and is used by several blockchain applications including Stellar, Ripple, and Hyperledger. This consensus mechanism derives its name from the Byzantine general problem: the problem of getting generals to all agree on a common plan to attack a surrounded enemy. Almost all of the generals had to perform the same action (creating consensus) in order to ensure a successful mission. The difficulty was that the generals could only communicate by individual messages and never knew if the information was correct in terms of validity and integrity. In their original paper on the Byzantine generals problem (Lamport, Shostak, and Pease 1982), find that consensus is impossible to achieve if one third or more of the generals are traitors. One of the solutions offered by Lamport et al. is to open channels between generals to make it possible to verify the messages. Received massages can than be distributed through the network so that the generals (nodes) can act according to the most

frequently received message. The proposed message (transaction) needs only to be verified by two thirds of the network to get added to the blockchain. This is the main structure of the pBFT consensus mechanism. There is an important difference worth mentioning between the Ripple and Stellar systems: Stellar uses corn slices of nodes to verify large pieces of data, which makes participation on the network free from approval of authority and thus makes the Stellar system more decentralised than Ripple.

Directed Acyclic Graph (DAG)
The companies IOTA, Byteball, and Hashgraph work using a technology that their developers call the tangle. It is based of the mathematical concept of directed acyclic graphs (DAG). This system is not based on a blockchain but on a non-linear network of transactions called *sites*. A site contains the details of the transaction, such as the identity of the sender and receiver and the amount of coins being transferred. These sites (transactions) are linked with in- and out coming *edges*. Each site is linked to the tangle with at least two out going edges, a site is officially validated when it has two incoming edges, if not the transaction is not officially confirmed and is located on the end of the tangle. To add a new site (making a new transaction) on the tangle, a node (i.e. the computer the transaction is coming from) has to check with the specific algorithm if two sites on the end of the tangle are not conflicting. If one of the tips is a fake site, this site is ignored and an other site is selected. This creates a network that works more quickly as more sites are added, because every node has to check two sites before adding one; this solves the scalability problem of PoW en PoS caused by the network becoming slower as more transactions are added. In a blockchain, the number of confirmations of the nodes in the network determines whether a block can be trusted. In a tangle, this principle is worked out by its own weight and the cumulative weight of its sites. Its weight is determined by the amount of work done of the issuing node. The cumulative weight of a transaction is the transaction's own weight plus the sum of the weights of all transactions that directly or indirectly approve this transaction (Popov 2018).The transaction with a high cumulative weight is older because it has more direct and indirect verifications, and therefore it is more trustworthy. Each transaction added to the tangle increases the ancestors' cumulative weight by the weight of that transaction. The use of this cumulative weight helps to avoid malicious attacks, as it is assumed that no entity can generate an abundance of transactions with an acceptable cumulative weight in a short period of time. For a more extensive explanation, see the white paper by Iota (Popov 2018).

Figure 11: Tangle vs blockchain, Source: IOTA Support 2018

The consensus mechanisms described in this section are the most frequently used mechanisms for bringing consensus to blockchain networks and thus provide a solid foundation for further research. However, two other characteristics must

be considered in order to develop the business model of securitisation based on blockchain technology. Distinctions must be made between private, public, and consortium blockchain and between permissioned or permissonless blockchain.

2.2.4 Private, public, consortium, permissioned and permissionless blockchains

When existing parties begun to explore blockchain applications for their current business models and processes a need for different blockchains with their own characteristics emerged in the process. The differences between a private, public and consortium blockchain are found in the amount of privacy in the network. Permissioned and Permissionless blockchains are different in the way they trust their nodes by validating transactions and controlling the network. To get a insight in these characteristics, the differences will be briefly discussed.

Public
In a public blockchain, anyone with a computer and Internet connection can access the blockchain and view the ledger (Gabison 2016). Because everyone can see the ledger history, this increases security and transparency of the network.

Private
In a private blockchain, only on party is able to view the ledger (Gabison 2016).). This increases the privacy of the network's users. On the other hand, it does not offer the level of security and transparency of a public blockchain. Nevertheless, private blockchains are mostly used by financial or governmental services to automate traditional business processes (Thompson 2016).

Consortium
A consortium blockchain is partly private and partly public. It is private in that only certain users can view the ledger. It is public in that there is no single party that can carry out control; this is done by all authorised users. This allows more transparency than to the private blockchain but still keeps privacy intact. This makes the platform appropriate for organisational collaboration purposes.(Thompson 2016).

Permissioned
In a permissioned blockchain, users of the blockchain need authorisation from the network operator to generate and validate transactions. A permissioned blockchain allows the network operator to maintain trust and control the network.

Permissionless
In a permissionless blockchain, all participants with a computer and network connection are welcome to participate in different tasks of the network. If a user decides to participate in the network, no permission is needed. The operator is fully confident that the technology will sufficiently control the network.

The blockchain technology behind Bitcoin is a public and permissionless blockchain; therefore, every user can participate in the network without any permission. With many users (nodes) the blockchain creates a distributed network that prevent a single point of failure. It requires at least 51% of the

			Read (who can access the ledger and see transactions)	Write (who can generate transactions and send them back to network)	Commit (who can update the state of the ledger)	Example
Blockchain types	Public	Permissionless	Open to everyone	Anyone	Anyone (*)	Bitcoin, Ethereum
		Permissioned	Open to everyone	Authorised participants	All or subset of authorised participants	Ripple
	Private	Consortium	Restricted to na authorised set of participants	Authorised participants	All or subset of authorised	Multiple banks operating a shared ledger
		Permissioned	Fully private or restricted to a limited set of authorised nodes	Network operator only	Network operator only	Internal bank ledger shared between parent company and subsidiaries

Table 1: Public, Private, Consortium, Permissioned and Permissionless, Source: PwC 2018a

computing power of all the users to alter the blockchain data, this creates an extremely secure network. A additional challenge is the limited scalability and large energy consumption of a private, permission less network. The speed of the network decreases and energy consumption increases with every new node connected to the network. The advantages of the public blockchain are the degree of transparency and decentralisation, which are the heart of the Bitcoin project (Thompson 2016). The challenges are the advantages of a private blockchain, it is mostly reduced in users whereby energy consumption. But these networks are more sensitive to cyber-attacks of malicious nodes and fraud from the authorised parties. More combinations and examples of blockchain characteristics are illustrated in Table 1.

2.2.5 Blockchain regulations

Blockchain is a relatively new technology with many uncertainties, and authorised parties are busy with drafting law and regulations. However, laws and regulations based on blockchain do not have a broad enough scope to connect specific laws to this research . Two salient recent set of regulations are relevant to blockchain development; these will be discussed in the following section.

General Data Protection Regulation (GDPR)
If blockchain and other financial technologies are accepted worldwide, speculators expect that the online safety and transparency will increase. Blockchain in particular will indefinitely store the information in the network. To protect citizens' privacy, the European Commission created new legislation in this regard. General Data Protection Regulation (GDPR) is the new privacy law that was enacted on May 25th, 2018. The new law stipulates rules for companies, institutions, and associations on how they must manage the personal information of customers, suppliers, employees, and members and all other parties whose personal information is processed in the networks. Personal information is a broad term, but GDPR defines personal information as information that identifies a person. In addition, personal encrypted information in the blockchain is covered by these laws. The law grants citizens of Europe the right to apply for requests to modify or totally delete their personal information when they

are no longer needed for the original purpose. The concerned company has to follow up the request directly. These modifications will bring many difficulties with it, because blockchains are developed as a source of trust in which information is stored safely and unchangeable. It is not the intention of the blockchain to modify blocks in the beginning of the chain; when this happens all the blocks must be mined again and safety can no longer be guaranteed. Not only technical issues play a role in applying this law; the law obligates every data controller to adhere to the rules of GDPR. In private pre-commissioned blockchains, there are mostly one or two data controllers that have to comply the rules of GDPR. However, in terms of public blockchains like Bitcoin and Ethereum, it is nonetheless inconceivable that every node (user) will comply with these laws. Nonetheless, there are a couple of solutions that can be considered by developers to be compliant to this set of regulations. Firstly, personal information can be stored off-chain. This means that personal information is not encrypted in the blockchain network and is stored at another location. In this case, there is a link encrypted in the blockchain network that links the blockchain to the personal information. If the user then wants to delete the information, it does not have to "break" the chain. Another option is to integrate processes that makes personal information permanently inaccessible. An inaccessible list of personal information is then created by these processes. If these processes are applied is an open question because it harms the distributed environment of the blockchain. However, to make a blockchain application comply with the GDPR, blockchain developers have to consider these kinds of solutions.

Payment Service Directive 2 (PSD2)
PSD2 is a modern European perspective on the payment environment. The older view was holding back growth in commerce and finance with the enormous overhaul of cross-border payments within the European Union. This shift of regulation refers to the landscape of payments, it is likely to give blockchain application a boost instead of retain the development. This PSD2 regulation was enacted in early 2018 and its purpose is to change the way banks share their data. Banks have to share client information with licensed third parties if the client asks them to do so. This will benefit a wide range of financial service parties and fintech to take advantage of the important asset. This does not favor the big banks because they give up an important competitive advantage. It will benefit the disruptor by promoting innovation in the payment space. Given the ability to share data between financial services providers in a decentralised and transparent manner, blockchain technology could be an important part of the new system. It also could help in the anonymity of electric payments and the acceptance of going cashless.

2.3 Conclusion literature review

In this section, the two main concepts of this thesis, blockchain and securitization, are combined together, and the potential impacts blockchain technology could have on securitisation is discussed based on the literature review.

The first thing that can be concluded from the literature is that the use of securitisation to fund mortgages has decreased since the financial mortgage crisis. This is clearly depicted in Figure 3. However, the regulations and the economic environment of the relatively safe mortgage portfolios of commercial

banks are creating the incentive to use securitisation again.

Unfortunately, securitisation in its current state is a very expensive process because of the multitude of stakeholders and the expensive administration fees, such as management fees and system costs, attorney fees, rating and underwriting fees, and the additional administration costs. Unexpected costs are common in this process and must also be budgeted for. Another disadvantage is the significant amount of time a securitisation transaction consumes. The many intermediaries impede the process, and it often takes months before a transaction is completed. These cost and time factors make securitisation not suitable for medium and small transactions. Furthermore, there are significantly high risks when the securities are not properly regulated.

In many papers that were studied for this research, transparency is one of the most promising potentials of blockchain. Gibson argued that everyone with a computer can view the ledger of information on the blockchain (Gabison 2016), while Tapscott and Tapscott argued that blockchain is able to track transaction history and can function as an audit trail (D. Tapscott and A. Tapscott 2016). Finally, Thompson maintains that the degree of transparency and decentralisation is the heard of the bitcoin project (Thompson 2016).

This degree of transparency in data can be used to simplify the regulation of the securitisation process, which in turn makes market failures less likely. This thereby lowers the risk for investors what can lead to greater overall investor interest. Malinova and Park state that transparency is the most important driver of liquidity (Malinova and Park 2017). Asymmetrical information in investment products is still a large barrier to buying these kind of products. By reducing this asymmetrical information and giving the investor more understanding of his investment, the demand for these products can grow. This is why Malinova and Park note that the most transparent scenario will benefit the buyer of financial products through increased liquidity. This not only benefits the buyer of the securities, but can deliver benefits to the end of the chain. With a higher demand for these securities, prices will improve whereby the originator can issue mortgages with a lower interest rate. Furthermore, blockchain could be a way to reduce the corruption and price manipulation that is perpetrated by originators, regulators, exchanges, and listed companies in central banking (Raskin and Yermack 2016).

Many processes in the securitisation process are performed manually and a great amount of data transfer is not streamlined. Blockchain has the potential to bring all of these stakeholders to a single platform in which sharing information is easy and there is an immutable audit trail. It also creates a single source of truth that could be used for analysis and forecasts. This could lower costs and increase the speed of transactions, which produces a better time to market for these products (Lotz and Websky 2017).). Furthermore, in the white paper of the World Economic Forum entitled 'Blockchain Beyond the Hype: A Practical Framework for Business Leaders', a decision tree was developed which can determine whether to implement blockchain in a business process. While several questions can be answered on the basis of the literature, not all of the questions can be answered because these must be researched in this thesis. Questions concerning intermediaries, digital assets, and contributors can be answered in terms of blockchain (see Figure 12). Questions concerning control, public transactions, performance, and shared write access were only able to be speculated on until the present; these questions will be answered in

the final section of the paper with the final blockchain based model.

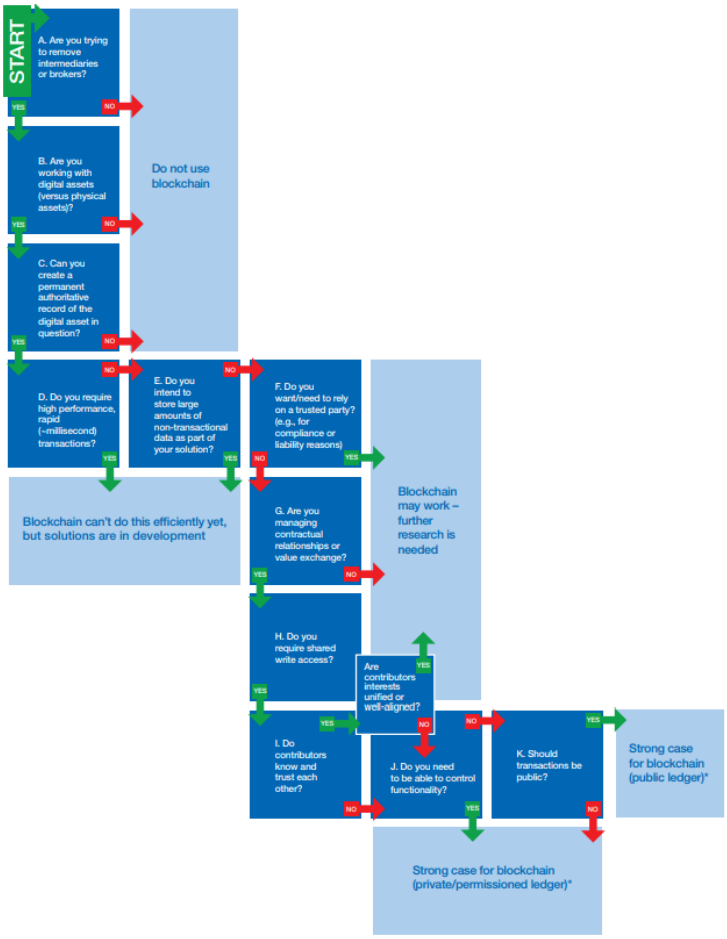


Figure 12: Decision tree blockchain, Source: Mulligan et al. 2018

Finally, in a guest lecture by Olivier Rikken, Rikken presented a decision tree on which kind of blockchain should be chosen for a particular business purpose (see Figure 13). Answers to these questions are also hard to derive without doing the necessary interviews. The model inclines toward a model with smart contracts for programming mortgage pools and different conditions, and transforming securities such as CDOs into assets traded over the blockchain require tokens. This leads to the use of the Ethereum network. This will be discussed further in the following sections.

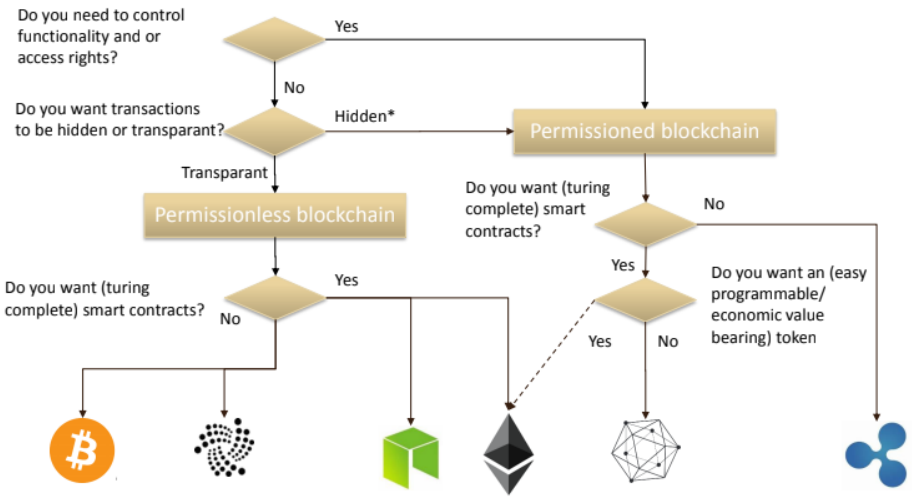


Figure 13: Decision tree which blockchain, Source: Rikken 2018

3 Methodology

In this chapter, the methodology of the thesis is discussed. The research strategy, unit of analysis, case selection, data collection, data analysis and design of the new business process model are thoroughly elaborated. Thereafter, the validity of the study is evaluated.

3.1 Research strategy

The purpose of this study is to examine how blockchain can make the securitisation process of mortgages more efficient and then develop this information into a valid BPMN model for a new business process. Because the blockchain technology is relatively new and the existing literature does not explicitly explore this problem, this current study is exploratory in nature (Shields and Rangarajan 2013). The research of this thesis identifies the obstacles to blockchain's implementation within the financial services sector of the Netherlands. The results of this study can lead to a better understanding of the existing securitisation process and the possibilities that blockchain technology offers. Combining the securitisation process with this new technology can ultimately improve the quality of the business process.

As this study is exploratory, it applies a qualitative approach, which is often used in exploratory research. This style of research employs techniques such as reviewing available literature, discussions with consumers, opinions of employees, ideas from management, in-depth interviews, focus groups, case studies and pilots (Sekaran and Bougie 2016). In this research, three of these main techniques are used: reviewing available literature, in-depth semi-structured interviews and discussions with experts to validate and evaluate the model. The literature is used to gain knowledge of the business process in securitisation and to review existing theories on blockchain technologies. Semi-structured expert interviews help to discover the opportunities that blockchain offers to the current securitisation process. Furthermore, the expert interviews are used to build a BPMN model from the current business process in order to fully understand the securitisation process. This step is in preparation of designing the new business process model; after all of the results of the interviews were analysed, a new business process model based on blockchain technology was designed. The program Visio is used to design both of the business process models in the BPMN. After the new business process model is created, discussions with experts are used to validate the research and the blockchain-based BPMN model.

To structure this process, and properly develop the new business process, the information system framework of Hevner is used. In this framework design-science and behavioral-science come together, they are needed to ensure the relevance and effectiveness of the information system research as mentioned in the scientific knowledge gap. The design-science research relates to the technology and focuses on creating innovative IT artifacts, the behavioral-science research focuses on implementation, organization, management and use of the technology. A common danger of the design-science research is to overemphasis on the technological artifact, resulting in a well-designed artifact that are useless in real organizational setting. Dangers of the behavioral paradigm are overemphasizing on contextual theories and failure to identify technological capabilities. Resulting in outdated an ineffective technologies (Hevner et al. 2004). Hevner

therefore argues strongly to respect both sciences in the information system research.

The framework uses three elements: the knowledge base, the environment and the information system research. In the knowledge base foundations and methodologies are developed using literature review. The interviews, stakeholder and the root cause analysis create the environment and describes the surrounding factors within the problem such as people, organizations and technology. The information system research is done in two phases. Developing the model and evaluating the model. Developing or redesigning is done with BPMN and thereafter the model is evaluate by discussions with experts. In Figure 14 the information system research is schematically shown.

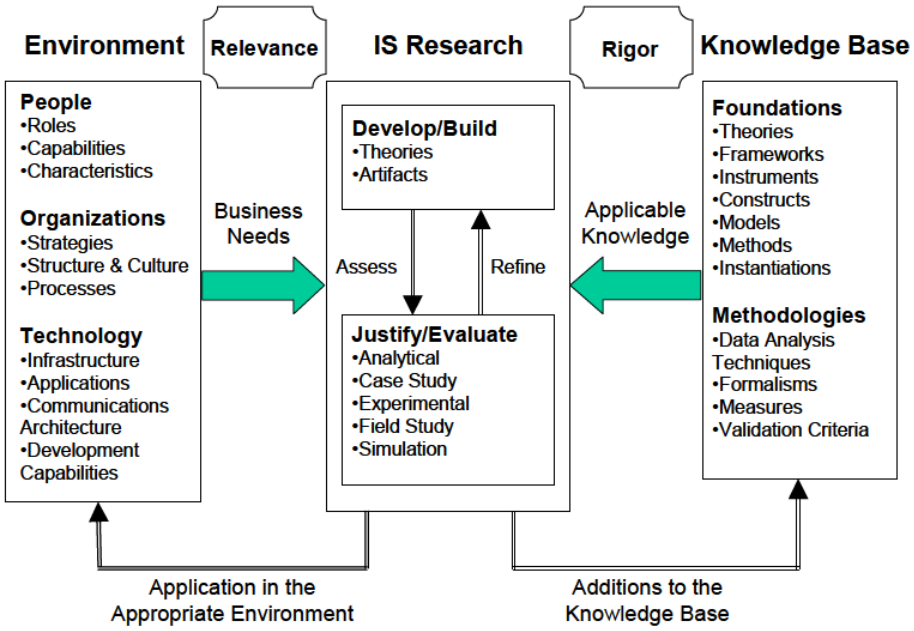


Figure 14: Information System Research framework, Source: Hevner et al. 2004

As mentioned above, this study concerns the financial service development departments of Dutch companies within the financial services and consultancy sector. Several semi-structured interviews were conducted to gather information about combining the securitisation business process with blockchain technology. The interviewees are experts in the field of financial services and work for the major trust, asset management, banking and consulting firms in the Netherlands. These companies are primarily oriented toward developing new financial technologies. Most of the interviewees work for different companies or different departments within the same company to increase the generalisability and validity of the results of this study. While the structure of the interview was similar for each interviewee, it is possible that every interviewee discusses individual insights of the problem or distinct solutions to the problem. When analysing the results of the interviews, the study compares the similarities among them to form thorough decisions.

3.2 Data collection

Data were collected by the most frequently used exploratory research techniques: literature review and interviews. Both methods are briefly discussed in this subsection.

3.2.1 Literature review

A literature review is also known as textual sources and desk research. In this method, the researcher uses the Internet, libraries and archives to find sources of information. Scientific papers, books, websites or other sources of knowledge that have been written by others are studied as sources of data and are included in the literature review (Cooper 1998). If literature is used in the thesis, a reference mentions the source.

A literature review was done for the first two stages of the research, as indicated in the research diagram, which can be found in Appendix A. In the first two stages, literature was reviewed for theoretical purposes and to gain knowledge about the two main concepts of blockchain and securitisation. Later in the thesis, literature is also used to expand knowledge about unknown subjects that emerge through the study. In stage 1, the research design is developed, including prior knowledge about blockchain and the securitisation business case required to find the appropriate problem. In the second half of stage 1, a chapter was written to clarify the main concepts for the reader. Knowledge had to be acquired about the main concepts of securitisation, residential MBS s (RMBS), blockchain and smart contracting before proper interviews could be held about these subjects. In stage 2, knowledge from the literature review is applied to design a suitable BPMN model of the current situations and discover the opportunities that blockchain can provide to improve securitisation. Facilitating an interview about a subject requires a certain amount of knowledge, so the literature review was used to gain this knowledge too. Blockchain is a relatively new technology, so relevant literature can mostly be found on the Internet. Keywords, cross references on Google Scholar and other websites were used for the necessary literature. This literature review is fully described in Chapter 2.

3.2.2 Semi-structured expert interviews

Interviewing is a qualitative research method that is often used in exploratory research. It consists mostly of a conversation between two persons during which time questions are asked to one of the persons who is a particular actor with knowledge about a specific topic. Interviews are suitable for in-depth questions or broader ones. With this technique, a complete view of the problem at hand can be created with the insights of the interviewee (Research Methodology 2018).

The data from the interviews are used in stage 2 and stage 3 in this research. With this data, the researcher developed a BPMN model of the current system to uncover the opportunities of blockchain. The data from the interviews were also needed to redesign the current process into a blockchain-based securitisation process. The opportunities of blockchain for the securitisation process were mainly explored by conducting semi-structured, one-to-one interviews with consultants and managers in their everyday environment. This exploratory way of interviewing allows in-depth discussions, which can provide the interviewer with

rich information. Business experts in the field of securitisation, consultancy and financial services firms were interviewed.

Six interviews with experts of blockchain and securitisation were held. These interviewees are members of the companies PwC and Intertrust. All six interviewees were interviewed according to the semi-structured interview protocols in Appendix J.1 and J.2. Protocol J.1 lasts for 60 minutes and contains more questions, when an interviewee asked for a short interview, protocol J.2 was used. All three interviews took approximately 50 minutes each. The intention of the interview protocol is to act as general rules and guide the interviews; that way, their structures are similar enough that it is possible to compare them. Therefore, the reliability of this study increases (Yin 2009).

In addition, all interviews were recorded and transcribed, while guaranteeing the privacy of the interviewees. The semi-structured interviews consisted largely of open-ended questions to allow the participants to convey their personal insights and expressions about the target concepts. When interviewees suggested opportunities or obstacles, they were asked to provide evidence of examples to demonstrate that it was not merely an opinion. Questions were asked in a manner that encouraged extensive discussions. To ensure anonymity, the names of interviewees are not released. The interviews are displayed in Table 2

Interviews				
#	Company	Function	Industry	Expertise
A	Intertrust	Director	Asset management	Securitisation
B	PwC	Senior Associate	Risk Assurance	Securitisation
C	PwC	Manager	Risk Assurance	Blockchain
D	PwC	Manager	Risk Assurance	Blockchain and Securitisation
E	PwC	Senior Manager	Assurance	Securitisation
F	Strategy&	Associate	Strategy	Blockchain

Table 2: Interviews

3.3 Data analysis

Analysing interviews is a multi-step process to make sense of interviews, and coding this data contributes to this understanding. Unfortunately, there is no universal consensus on a coding procedure that can be easily replicated (Coffey and Atkinson 1996). In this research, interview data was fully transcribed according the recordings, as this is an important step in phenomenologically analysing interview data (Hycner 1985). After the transcription, the transcripts were read again by the researcher to reduce misinterpretation of the answers. The transcripts can be found in the additional document 'Interview transcriptions' to ensure the privacy of the interviewees, the recordings are not included. It is possible to listen to the recordings on request and in the presence of the researcher. This stipulation is necessary for meeting the terms of the interviewees, who were guaranteed that the recordings would not be published.

The second step is coding the responses, which is a typical initial step in analysing interview data. Codes are defined as:

"tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study"(Miles et al. 1994).

In the coding step, researchers must label relevant pieces of information in the transcripts. In this research, the labelled information relates to the current securitisation business process, opportunities for the implementation of blockchain, opinions of the interviewees, future perspectives of securitisation based on blockchain and other information that directly relates to the research questions. These labels are important because they help to highlight phrases or ideas that are repeated several times and ones that interviewees explicitly stated to be important, or they also can remind the researcher of the specific research topic. The interviews were semi-structured and thus at times deviated from the subject. This structure fits the exploratory nature of this research, so the labels used in this research were deemed relevant by the researcher. The codes and meanings can be found in the codebook.

The codebook has two functions: the first is to help the researcher by analysing the interview data. "Codebooks are important to analyze qualitative research because they provide a formalised operationalization of the codes" (DeCuir-Gunby, Marshall, and McCulloch 2011).). The second function is to more easily refer to the interview data in the thesis. In the codebook, the goal was to achieve a balance between simplicity and detail for the researcher to more easily distinguish between sets of information without missing necessary ideas. The information from the codebook was used to make decisions in the next phase of designing the new business process model. The codebook is digitally included with the thesis in a Microsoft Excel file. In the codebook are codes that refer to a phrases in the transcriptions. Interviews are indicated with letters A to G and the discussions are labelled with a combination of letters VA to VE. When a code refers to a specific interview, the letter or combination of the interview is first indicated and then the code. For example, A.BENFSEC refers to the interview A and the code BENFSEC with the remark 'benefits of securitisation'. Combinations of interviews are possible too, such A.C.CDO, which discusses collateral debt obligations in interviews A and C.

3.4 Design of the new business process model

This section discusses the three design tools that were used to create the new business process model. First, a root cause analysis was performed to create a better understanding of the issues involved in the process. The identified issues, in turn, helped when creating the proposed improvements.

3.4.1 Root cause analysis

In the literature, there are many definitions given for root causes. In this report, the definition of Rooney and Heuvel (2004) is used:

1. Root causes are specific underlying causes.
2. Root causes are those that can reasonably be identified.

3. Root causes are those that management has control to fix.

4. Root causes are those for which effective recommendations for preventing recurrences can be generated.

Brainstorming about the root causes creates a better understanding of the issues, which in turn proffers grounds for the considered improvements. The root causes can be visualised using a fishbone diagram. For the business process of securitisation based on blockchain, the fishbone diagram is used (CMS 2018). The root causes can be visualised using a fishbone diagram. For the business process of securitisation based on blockchain, the fishbone diagram is used. The main goal of this business process is to withdraw loans from the balance sheet of mortgage originators to ensure that they meet the requirements of governmental policies, like the Basel accord. However, the costs of this business process of securitisation are enormously high due to the many stakeholders involved, all of whom charge their own high fees. This process can be improved with blockchain technology to reduce transaction costs and time. The main issues to address in redesigning this business process are 'regulations', 'stakeholders' and 'technology'. These points are elaborated in the chapter which describes the designing phase. This analysis offers more insight into the core problems, which resulted from the root cause analysis diagram found in Appendix C.

3.4.2 Stakeholder analysis

A stakeholder analysis is a tool to generate knowledge about the actors involved in a business process. It is important to understand their behaviour, intentions, interrelations and interests while assessing the influence that the actors bear on the decision-making or implementation processes (Varvasovszky and Brugha 2000). Stakeholder analyses can be used for several purposes in the fields of policy, management and project implementation. A stakeholder analysis is used in this report to identify all of the stakeholders involved in the business process of securitisation, which enabled the researcher to identify which stakeholders would be eliminated by the implementation of blockchain technology. Identifying all of these stakeholders provides knowledge about the role of each stakeholder and estimations of their level of resistance against blockchain implementation. The stakeholders are listed in a table with their responsibilities in the current process and potential future blockchain-based process, their interests (or stakes), the influence they have on the project, the impact the project has on them and their stance on the project. The stakeholder analysis for this research is elaborated in the chapter about the business model design and in Appendix B, where tables of the stakeholder analyses from the current and new situations can be found.

3.4.3 Business process model notation (BPMN)

In the thesis the BPMN is used to design a structure the securitisation business process. This notation is an international standard that uses specific signs and rules (Chinosi and Trombetta 2012) and is used by companies all over the world to clearly show the details of business processes. Two visual models were made to represent the business process. The first model demonstrates the current securitisation process to offer a stronger understanding of this business process and identify opportunities for enhancements. The second model is the

Discussions				
#	Company	Function	Industry	Expertise
VA	PwC	Senior Associate	Risk Assurance	Securitisation
VB	PwC	Senior Associate	Risk Assurance	Securitisation
VC	PwC	Partner	Risk Assurance	Securitisation and Blockchain
VD	PwC	Senior Associate	Risk Assurance	Blockchain

Table 3: Discussions

business process model based on blockchain. By comparing these two models, the advantages and improvements that blockchain can brings to this process are evident. However, many stakeholders such as managers and policy makers are important decision makers in this process. BPMN models are able to clarify these complex IT business processes by using a notation that feels intuitive for technical and less technical decision makers (White 2016). This could help these actors to understand the complex concepts behind the technical process and may increase incentive to implement blockchain in the current business process. The business process design is elaborated in chapter five.

3.5 Validity and reliability evaluation

To guarantee the highest possible validity and reliability of the data and findings in this research, the final results were discussed with experts in the field of blockchain and securitisation. Furthermore, construct validity, internal validity, external validity and reliability were considered (Yin 2009).

3.5.1 Expert discussions

A focus group is a qualitative research method used to guide an open discussion about market research, political analysis, new products or product implementation. In a focus group, diverse people are asked about their perceptions, opinions, beliefs and attitudes about a product, service or concept (Kitzinger 1995).However, researchers must be judicious in their claims of expert validation (Sandelowski 1998).

The focus group is divided into four expert discussions, which were used in stage 4 to validate the new business process solution. The interviewees were asked to participate in the expert discussion, if possible, while new experts were invited to this discussion for an unbiased outcome and to increase reliability. The discussion was guided to ensure the it did not stray to another subject. To start the discussion, the final result of the proposed solution was shown to the experts, and questions were asked about the findings from the research. Additional findings are deliberately included in the new business process model. The guidelines of the discussion are presented in Appendix K in the discussion protocol, and the findings of these discussions are presented in Chapter 6 of the thesis. In Table 3, an overview of the discussions is displayed.

3.5.2 Construct validity

Construct validity was increased by identifying the correct operational measures for the concepts studied (Yin 2009). Multiple interviews were held according the interview protocol. The interview protocol is based on the literature and aimed to find the correct operational measures for the target concepts. Furthermore, during the interviews, the concepts and context in which they should be understood were thoroughly explained by the questions. During the interviews, the main findings were repeated to verify whether all of these findings were correctly interpreted.

3.5.3 Internal validity

"Internal validity refers to the degree to which a researcher is justified in concluding that an observed relationship is causal" (Johnson 1997). To increase the internal validity, patterns from the codebook of the interviews could be matched. By comparing the outcomes of the interview data against each other and counting the number of repeated subjects, internal validity of the findings can be tested.

3.5.4 External validity

"External validity is important when the aim is to generalise from a set of research findings to other people, settings or times" (Johnson 1997). In this research, the external validity is increased by interviewing experts who come from different companies and departments, and their level of work experience differed as much as possible. However, all of the experts are specialists in blockchain or securitisation in order to ensure a meaningful discussion. The results of the interviews were compared to progress the decisions for the model. If the findings conflict across the cases, it could influence the generalisability of the research.

3.5.5 Reliability

A study shows reliability if the operations of the study can be repeated with the same results (Yin 2009). To increase the reliability of this study, an interview protocol was used, which can be found in Appendix J. The interviews were conducted as similarly as possible by following the procedure in the interview protocol. The interviews were semi-structured, which influence the reliability. By duplicating the interviews with the same interview protocol, most of the findings can be compared. The codebook also increases reliability, as it functions as a database in which all evidence can be directly accessed following the codes. Finally, the reliability is increased from the selection of only experts in the field of blockchain and securitisation in the Dutch financial industry.

3.6 Research flow diagram

To summarise the methodology of this research, a research diagram was created. This diagram can be found in Appendix A. The research consists of five stages. The arrows in the diagram display the data that developed the findings that were used in the concept understanding and analyses (red boxes). The purple boxes represent the explanations of what was done, and the corresponding green

box shows the final deliverable from that stage. A research planning was also planned and can be found in Appendix H.

4 Analysis and findings

This chapter includes an analysis of every interview that was conducted for this research. First, general information about the interview is provided. Then, an analysis is done of the interviewee's responses to the research questions. Finally, additional findings and unexpected answers that are important to this research are assessed. After every statement, there is a corresponding code that can be found in the transcripts and the code book.

An interview matrix is displayed in Table 4. This table provides as overview of the detailed information from each interview described further in this chapter. The left column (Int.) lists the interviews. The second to fourth columns represent short answers addressing the research questions of the thesis. The last column includes additional findings.

Additional to the interview matrix every interview is discussed briefly in this section. To start with interview A, this interview is held with a securitisation expert. In the awnsers can be seen that this interviewee knew a lot about the process itself and the different steps that must be taken in the securitisation process. Laws and issues of the securitisation process are discussed to. On the side of the technology the interview was less informative. Smart contracting, private and public blockchains were discussed. But the most interesting point was that he disagreed with the fact that the originator has to take the lead with innovation. This innovation must come from a start- up or disrupter in the market following interviewee A.

In addition to the interview matrix, every interview is discussed briefly in this section. The first interview (Interview A) was held with a securitisation expert. This interviewee was knowledgeable about the securitisation process, both as a whole and in terms of the individual steps. Laws and issues of the securitisation process were also discussed. On the technology side, the interview was less informative. Smart contracting as well as private and public blockchains were discussed. Notably, he did not agree that the originator should take the lead on innovation; rather, he argued, the innovation must come from a start-up or disrupter in the market.

The second interview (Interview B) was also with a securitisation specialist, and subjects similar to the first interview were discussed. The importance of LTV, LTI (loan-to-income) and the creation of CDOs in the United States (collateral debt obligations) were discussed. Transparency and smart contracting interested interviewee B the most on the blockchain side.

The third interview (Interview C) was done with a blockchain consultant from PwC . Blockchain opportunities and functions were elaborated, including tokenisation, permissioned, private, or public blockchains and consensus mechanisms. Laws and issues with the securitisation process were also discussed.

The fourth interview (Interview D) was held with a manager in the risk assurance department of PwC that operated in both fields. He made a sketch of possible future perspective of the business process. Other topics include the valuation of tokens from the business process and the possible opportunities of blockchain.

The fifth interview (Interview E) was with a securitisation specialist who has worked worldwide in the field. Laws, issues, and the steps in the securitisation

process were discussed. He also mentioned the future prediction models that were important in managing the mortgage pool. Unfortunately, this lay beyond the scope of this research.

The sixth interview (Interview F) was with a strategy consultant who has done a project in the field of blockchain and securitisation before. Changes in the stakeholders of the securitisation process and their obligations were discussed. This provides a brief summary of the interviews; the following chapter elaborates upon and analyses the interviews further. Transcriptions can be found in the interview appendix.

Int.	RQ 1	RQ 2	RQ 3	KF
A	- Using smart contracts (smart) - Securitization is time consuming (time) - Clearing and settlement perfect to implement blockchain (CLEAR) - Cashflow to investor must be made more efficient (CASH) - Liquidity issues with RMBS (LIQ) - Blockchain could increase, speed and reliability and reduce costs (COSTS,TIME,REA)	- The system needs to meet regulation and supervison (LAWSEC) - Risks must be controlled with framework (CONBL.) - Reliability must be guaranteeds for customer, robust system (REQBL)	- Blockchain would reduce number of stakeholders (STASEC) - Make assets more liquide (LIQ) - Meet law and regulations (LAWSEC) - Build a regulatory and risk/control framework (CONSEC)	- The expectation that the bank is not able to implement this technology, a disrupting party will take te lead in these technology transformations (LEAD) - When banks implement blockchain, it would be a private network (PRIPUB) - Energy consumption would not cause a problem (FACHAMP) - A robuste system is important, in case of data loss (error free) (FACHAMP) - No personal information on the blockchain (INFOON)
B	- Liquidity issues with RMBS, tokens will open new market (LIQ) - Tasks of SPV, Investment bank, paying agent and trustee are discussed - Redemption is quaterly paid out and interest monthly (MONPAY) - Because securitization is costly and time consuming it is not ferquently (COST,TIME)	- Risk and control framework (CONBL) - Controls, job, credit worthiness, own house (CONBL) - Meet regulatory (LAWSEC) - Skin in the game 5 percent for the originator (LAWSEC)	- Smart contracts by transfering money (SMART) - Blockchain has to bring more transparancy into the system (TRANS) - Cut a lot of expensive intermediaries out of the system (STAKE)	- LTI and LTV important risk measures (LTVLTI) - Collateral dept obligation are not in the scope of this research only R-MBS (CDO) - CDO squared products are not sold in The Netherlands (CDOSQ)
C	- Transparency is important for clients, investors and regulators (TRANS) - Securitization is a costly business process (COST) - Liquidity issues, tokens could be the solution (LIQ) - Manually tasks of auditors can be automated (HAND,AUDIT) - Controling processes (drafting, signing and managing contracts) could be automated (ADVISE) - Credit agencies could lose there function by the transparency of investment products (CRAG) - Exchanges will disapear because tokens are mutually tradable (EXCH) - Tokens must be traded on a exchange to increase liquidity (TRADSEC)	- Managing data, personal information not on blockchain (DATA) - Important to use not tracable data (SECU) - Old systems have to interact with new ones (FACHAM) - Meet regulatrity (LAWSEC) - Stakeholders hamper speed of innovation (STASEC)	- Private blockchain has preference (PRIBUP) - Consortium consensus mechanism (CONM) - Premissiond blockchain (PREM) - Throughput is low by ferquency of transaction (TRHOUGH) - Hypotoken for information Secutoken for trade (TOKO) - The value of the token must be linked to the cash flow from the borrower (TOKO)	- LTV is important but LTI is Codebook2!E5 it is personal information as wel (LTVLTI) - Smart contracts can be used for controls (SMART) - Transparancy can be used to simplefy governance (TRANS) - Laws have to change before implementing blockchain applications (LAWSEC) - Copy current situation with blockchain layer, then change enviroment (PRESECBL)
D	- Securities must be converted to tokens (TOKO) - Liquidity issues with RMBS (LIQ) - Automation of managing mortgage pool (MMP)	- Swap profider is not important in the business process (SWAP) - Exchange is needed (EXCH) - Smart contracts prevent double controls and can take over controls (CONSEC)	- Tokens must be linked on mutliple loans (TOKO) - No data on tokens, same as bonds on bond papers is no data of investment	- Keep interest and redemption payment and pay this out when token is sold back (MONPAY) - Token can be valued like a bond (BOND)
E	- Low default decrease costs (DEFBL) - High cost securitization process (COSTS) - Redflag defaults, not take them out of mortgagepool (MMP)	- Control framework is important for banks - Risk diversification in financial products is important (RISKSEC) - IFRS accounting rules are important to implement (LAWSEC) - Interfacing problem is huge with implementing new technologies (REQBL)	- The system has to deal with irregular payments (CASH) - Mature loans and defaults need to be replaced (MMP) - Low interest rates and rising house prices increase demand of R-MBS (IWT)	- Prediction models are a kind of controls, these are important to build in the system to manage de mortgage pool (CONBL,MMP)
F	- Not discussed	- Bank have to met the requirements of Basel 4. (LAWSEC) - Transparancy is important for the increased supervison. (TRANS)	- Auditors get less work by implementing blockchain, double check are unnecessary (AUDIT) - Clearing is much faster, and clearing houses will dissapear (CLEAR) - Exchange will be needed, but more like token exchange. They have to innovate (EXCH) - Custodian companies get a more important role and have to innovate (CUSTO) - Credit agencies are still iimportant in a blockchain based system (CRAG) - Value the token like a bond is a good option (BOND)	- Sell only the credit risk of the token, to get a kind of insurance on the token(CREDIT)

Table 4: Interview matrix

4.1 Interview A

The first interview was held with the capital markets director at Intertrust together with a PwC employee who initially connected the director with the researcher. The interviewee was also a speaker at the ASB global conference in Barcelona. Intertrust is one of the intermediaries in a securitisation transaction and is called the trustee. They take care of the interests of the investor. For example, they approve the prospectus of the securitisation transaction to prevent any misleading information. The interviewee and the employee are held anonymous and are called interviewee A (IA) and employee A (EA). The total length of the interview was 51 minutes and is transcribed in the interview appendix as interview A.

4.1.1 Analysis

To answer the first research question, a couple of subjects are discussed in the interview. The first research question was:

'What is the current status of the business process securitising mortgages and what opportunities could blockchain bring within the status quo?'

IA first discussed the labor intensive parts of the business process of securitisation. He gave examples: drafting contracts, sending contracts back and forward by email, signing contracts and delivering contracts at tax authorities. In all these steps multiple contracts are made. For example, by sending a contract by email, the contract is duplicated. Blockchain offered for him opportunities to prevent this duplication of contracts. One version of the contract was of particular importance for IA. He also argued that the pledging of mortgages from originator to SPV was time consuming and expensive. He considered smart contracting the solution to make this process more efficient in terms of time and costs (A.SMART).

In addition, clearing and settlements of MBS was an antiquated process following AI. He augured that these labor intensive tasks were perfect to implement blockchain (A.CLEAR).

The cash flow of the interest and redemption payments are also processed with many intermediaries. To make this process more efficient and reliable, he recommended also smart contracting (A.CASH).

Liquidity was also an interesting point for AI; he stated that these RMBS securities are traded in packages of 100, and every security costs 1000 euro. They only traded these securities with institutional investors. He discussed the crowd funding initiatives in England to offer loans to the public, but he noticed that this only can happen with the adequate regulation (A.LIQ).

In addition, AI mentioned that implementing blockchain could reduce costs by eliminating different intermediaries in the process, but he also argued that when you eliminate intermediaries the speed of the process would increase. This would increase the time to market and create fairer prices of products. The elimination of intermediaries would also increase the reliability of the data stream because the change of manipulation could decrease (A.BENFBL).

'What are financial service institutions' requirements for a new RMBS busi-

ness process based on blockchain technology?'

The most important requirements for a new MBS business process for AI were that it meets regulatory laws and fits the supervisors' requirements. EA noticed the AFM and the DNB as supervisors and Basel accords, WFT and solvency 2 as applicable laws (A.LAWSEC).

To meet the requirements of all regulators, a regulatory framework must be set up, AI told. This must be investigated further before implementing blockchain applications. Afterward, controls can be based on the regulatory framework; input controls were of the highest importance for AI because input was difficult to change in blockchain networks (A.CONBL).

A reliable process must be guaranteed to the customer, AI agreed. This can be guaranteed when manipulation of contracts is decreased. This can be performed with blockchain or smart contract implementation as mentioned above (A.REQBL).

'What would a new blockchain-based securitisation business process model look like?'

AI was enthusiastic about smart contracting and its self-executing functionality, and mentioned that this new technology is special for managing the interest and redemption payments of the RMBS. The blockchain technology itself would increase the time to market and speed of the transactions. It also makes many expensive intermediaries redundant and reduces the chance of fraud. It was clear that the RMBS were only traded with institutional investors in large volumes, but he was curious about makiing those assets more liquid, mentioning the crowd funding initiatives. However, the system has to meet the required regulations before implementation. He recommended conducting research on the regulatory and control framework for blockchain before implementing these blockchain-based business processes to guarantee a reliable process for the customer and investor.

4.1.2 Additional findings

In the interview with IA the arranger or lead manager was discussed. This was brought into the discussion when the party was asked who will take the lead in blockchain-based securitisation transactions and who would bear the costs. He gave an example of how banks finance inland vessels, here bank takes the lead in the communication, linking investors to the investment and managing the cash flows. He argued that these "small" funding transactions were also suitable for blockchain applications. However, he was in debt if the bank was also taking the lead when IT processes are central in the finding process, pointing to smart contracts and blockchain. The innovation of financial business processes mostly come from small emerging parties; he mentioned a party that created its own platform to process different customer files and to create a "know your customer" check. Based on this information, the platform could generate a credit score of a customer. Banks are unfortunately too big to change these business processes, although they will take over these companies in possession of these technologies or create collaborations with these start-ups (A.LEAD).

In the interview, two aspects that impeded blockchain innovation were discussed. The interviewee had a question at the ABS conference in Barcelona on how blockchain is dealing with the energy consumption . Because of the enormous quantity of computing power it needs to automate this blockchain processes. AI stated that when a blockchain-based securitisation process is implemented, it would not be a public blockchain (PRIPUB). A private blockchain reduces energy consumption because there are less nodes involved and there are not as many transactions as within the Bitcoin network. Furthermore, he argued that the energy consumption will decrease when technology development continues. In addition, the robustness of the technology was also an important aspect for AI. In terms of new innovations, it is important that the technology does not make any mistakes. This can cause fatal data loss, faults and errors what can hamper implementation of blockchain business processes (A.FACHAM).

There was also a short discussion of information in the blockchain. The researcher asked if he knew what kind of information from mortgages was most important in securitisation transactions. Unfortunately he did not know, but he concluded based on the questions that personal information should not be included in the blockchain (A.INFOON).

4.2 Interview B

This interview was conducted with a senior consultant from the risk assurance department of PwC , referred to as interviewee B (IB). This employee previously worked for four years at an international trust and corporate management company Intertrust . In four years at PwC, he had worked for several clients involved in the securitisation processes. The interview lasted around 60 minutes and is transcribed in the interview appendix as Interview B.

4.2.1 Analysis

'What is the current status of the business process securitising mortgages and what opportunities could blockchain bring within the status quo?'

In the beginning of the interview, IB talked about institutional investors and the ways in which investors are limited. He noted that RMBSs are bought by large pension funds and insurance companies. Therefore, the normal investor is excluded, even though there is a demand for this kind of investment. This could be a reason to bring affordable RMBSs to the market, this would increase the liquidity of RMBS. These products could be transformed into affordable tokens, according to IB (B.LIQ).

In addition, the status quo of the duties of the SPV, investment bank, trustee, and paying agent were discussed. IB noted that the SPV is created by the originator in cooperation with other legal parties to sell the securities. The SPV is then the owner of the mortgages that are sold as securities, RMBSs, to investors (B.SPV). The investment bank helps the SPV bring those securities to market. The investment bank acts as a broker, bringing the buyer and seller together (B.INBANK). The trustee is the manager of the mortgage pool owned by the SPV (B.TRUSTEE). The trustee calculates the interest and redemption payments, and the paying agent recalculates these figures. If there is consensus

about the payments, they are paid to the investor. Redemption payments are paid quarterly and interest payments monthly (B.MONPAY).

Securitisation is done for about one third of the originator's mortgage portfolios. The rest of the portfolio is sold in other ways that are outside the scope of this research. This indicates the importance of securitisation in the Netherlands, which totals 500 billon euros in mortgages (B.SEC). An important reason for securitisation, according to IB, is that the credit rating of the SPV is often better than that of the SPV. With a better credit rating, it is possible to borrow money at a better rate. The mortgage also has a lower cost when owned by the SPV than the originator (B.BENFSEC). Unfortunately, these transactions are time consuming and expensive, according to IB. A securitisation transaction can cost 1% in transaction fees because of all of the costly intermediaries; this is 1 million euro on 1 billion euro in yearly costs. IB thinks that blockchain could reduce the transaction times and costs by cutting out intermediaries (B.BENFBL).

'What are financial service institutions' requirements for a new RMBS business process based on blockchain technology?'

The risks and controls (supervisory and regulatory) were also discussed. Commercial banks assess risks in part by screening their clients, which is known as the creation of the 'know your customer' profile to determine the creditworthiness of the customer. It is important that the borrower has permanent employment to pay the cash flow and lives in their own home, because this is the best incentive to pay the mortgage. This indicates that a good risk and control framework is necessary to implement a new MBS business process. But this is not a requirement only for the originator but mostly for the investor, the final stakeholder that would lose money when controls are not well executed (B.CONSEC,CONBL).

Legalisation was not discussed much in this interview. The concept of 'skin in the game' was. IB says that an originator should hold a minimum of 5% of their mortgage portfolio on their balance for regulatory reasons; this 5% often consists of a 'vertical slice', which consists of RMBSs with credit ratings ranging from AAA to D (B.LAWSEC).

'What would a new blockchain-based securitisation business process model look like?'

IB did not provide a clear answer on this question. However, IB discussed smart contracting and how these contracts could transfer value on the basis of agreements. In addition, mortgage deeds could be placed on the blockchain in order to increase transparency. Therefore, the system must use smart contracting to transfer money, and the main purpose of blockchain would be to add more transparency in the system and to information. When using blockchain IB agreed that blockchain could cut out many expensive intermediaries, which would decrease transaction costs and times.

4.2.2 Additional findings

This interview also included the topics of LTV and LTI ratios, which are important risk drivers of the securitisation process. After the financial crisis of 2008, the LTV ratio was lowered from 106% to 100% to prevent residual debt. This could be a large risk for the investor. Also, the LTI is important in preventing a borrower from spending an excessively large portion of their wages on mortgage payments. In the Netherlands, a mortgage is on average 4.5 times the annual wages, according to IB (B.LTVLTI).

CDOs were also a main topic of this interview. CDOs can be created from any type of loan (e.g., car loans, business loans, or credit card loans). RMBSs, the primary focus of this research, are based on mortgages. They have, through the securitisation process, the same working principle as CDOs. They are both owned by an SPV and get pooled for sale to investors. It is important to focus on the RMBSs in this research and leave CDOs to the side, as it is not within the scope of the research. CDO squared products were also brought up; however, these are not sold in the Netherlands and so will not be further discussed (B.CDOSQ,CDO).

4.3 Interview C

This interview was held with a PwC manager from the risk assurance department, referred to as interviewee C (IC). This employee had worked at PwC for 7 years for several clients involved in the securitisation processes and transformation to blockchain technology. The interview was 42 minutes long and is transcribed in the interview appendix as Interview C.

4.3.1 Analysis

'What is the current status of the business process securitising mortgages and what opportunities could blockchain bring within the status quo?'

In the interview, IC talks about his experience in the field of blockchain. He talks about a project run by a large bank that is researching the opportunities for using blockchain in the mortgage market. He argued that the blockchain's transparency could help provide clients and investors more insight into the cost structure of investment products. This could increase competition in this sector and tighten the prices of investment products or loans (C.TRANS).

As in Interview B, the costs and time of the transactions came up. IC said that the costs of setting up a securitisation transaction were enormously high: often, 1% of the value of the whole transaction. And these were only the costs of the auditors and the legal organisations working on a transaction (C.COST).

The liquidity issue was also discussed again. Because of the large packages of bonds currently being sold, there is a need in the market to sell these products in smaller pieces. This would give the normal investor exposure to the mortgage market in addition to the institutional investors. Tokenising could be a solution for this problem, as described in the third sub-question (C.PACK).

These costs are not one-time costs; auditors are paid periodically, which results in higher costs over the whole life cycle of the transaction. These costs are needed for periodic controls to verify whether the mortgage pool meets the

investor's yield requirements, which were previously agreed upon with the financial institution. Changes in the mortgage pool in the case of default or payment arrears can cause changes in yields. In the current system, these checks are done by hand using samples taken by auditors, which also entails a considerable risk. In the blockchain process, mortgages are dropped when they no longer meet the requirements of the mortgage pool. According to IC, blockchain could improve this process and help manage the default process (C.HAND,AUDIT).

The financial advisor role is also in danger, according to IC. He argues that blockchain could decrease the number of control processes, such as drafting contracts, signing papers, and managing the paperwork. The role of the advisor will disappear if smart contracting is implemented. However, good client advice is always needed and adds value to the role of advisor (C.ADVISE).

Credit rating agencies are also stakeholders that could lose their role in the future. They are parties that assess a mortgage portfolio based on samples and their models. But this information is already known by the issuing party; they only need the stamp of the rating agency so that investors trust the products. If this could be accomplished with smart contracts, credit ratings lose their function (C.CRAG).

The function of the exchange where debt securities are sold is also disappearing. This is because tokens are mutually tradable, says IC (C.EXCH). He gives no further argumentation, and thus the researcher disagrees with this discussion point. Rather, an exchange is needed to create an international market, which increases the liquidity of the tokens. Exchanges must also change when tokens are sold instead of debt securities. They do not lose their function but rather must innovate. Later in the interview, IC contradicts himself by saying that the over-the-counter trade of debt securities must be changed to a trade on public exchanges in order to increase liquidity (C.TRADSEC).

'What are financial service institutions' requirements for a new RMBS business process based on blockchain technology?'

Managing data was an important requirement for IC. He argued that it was important to keep data on the blockchain that was not in conflict with the GDPR law or other regulations (C.DATA). So, personal information must be kept off the blockchain. It was also important to develop a system that works only with the necessary information, and if this information is hacked or stolen, the information must be unusable. For example, PwC considered creating a system for originating mortgages that uses only the LTV, NHG, and geographical information of the mortgage. This data was not traceable back to an individual but could create a risk profile for the investor (C.DATA,SECU).

When developing this new business process, it is important to implement blockchain applications in a way that they can interact with the older ICT systems of the bank. This is a major issue when implementing innovations, especially when considering that some banks still work with punch cards (C.FACHAM).

Supervision and the Basel IV accord were also discussed in this interview. There are two important components, according to IC. The first is that supervisors want more transparency in transaction costs as well as viability of these financial instruments, which refers to the EU law MiFID II. The second is the Basel IV accord. If banks could securitise more easily on a smaller and

cheaper basis, this could dramatically increase economic performance of the bank (C.LAWSEC).

Other parties hampering the innovation process were also discussed. In the securitisation process, it is important that all parties want to innovate. All parties have their own interests that they want to protect. An innovation plan for multiple stakeholders can, for this reason, be a very slow process. This is the disadvantage of implementing blockchain in business. Mostly, the innovation is not of a product but rather a whole ecosystem. This increases the value of the innovation, but can take a long time to implement (C.STASEC).

'What would a new blockchain-based securitisation business process model look like?'

Some technical aspects were discussed in this interview. IC had chosen a private blockchain for the large bank's project. But in this blockchain, many other parties needed to be plugged in, such as investors, valuators, and exchanges (C.PRIPUB). A consortium blockchain was a good alternative, because it allowed the involved parties in a securitisation transaction to bundle strength (C.CONM) and allowed the exclusion of malicious parties for security reasons (C.PREM). Throughput of transactions and scalability were also discussed, but IC saw no problems with those much-discussed subjects. Throughput of transactions is not too high, like in the Bitcoin network (C.TROUGH). This also decreases the scalability problem, which makes it a perfect business case, according to IC (C.SCALA).

IC also offered insight into how to use tokens in this business process. He says that there would be two types of tokens: the hypotoken (hypotheek token), or mortgage token, and the secutoken, or security token. The hypotoken would used to keep information about the customer, such as the LTV, NHG, and geographical location, to create a risk and value valuation of the token. This is similar to the front end between the customer and the bank. These tokens would be pooled into an hypotoken portfolio, from which secutokens would come with different risk profiles. He says every token could cost 1 euro, so that buyers can purchase the exact amount they want. These secutokens would be tradable on exchanges. IC is less clear about what the secutoken represents exactly and whether it is even possible (B.TOKO).

The management of the mortgage pool must be linked to the value of the investment. The investment represents a certain amount of redemption and interest payments, which are the yields for the investor. This cash flow must be linked to the borrower: when the borrower goes bankrupt, the cash flow stops. This must be represented in the value of the investment. This must be programmed in a smart contract. Furthermore, an investor would not want to buy a product that represents only one mortgage, as it would be too risky. It must be a pool of mortgages so that the risk is diffused. It could be possible to customise one's own risk with tokenisation, which could make investment in these products more attractive. With smart contracting, it could be possible to program a preferred LTV, with or without NHG, to create a personalised risk profile—something that many investors are looking for (C.TOKO).

4.3.2 Additional findings

Other interviews include discussion of LTV and LTI, but in this interview, IC argued that LTI is not important for securitisation. The LTI, or ratio between the loan and income of the individual borrower, is less important than the risk indicator of the ratio between the loan and value of the collateral. Furthermore, the income of a borrower is also sensitive personal information (C.LTVLTI).

Regarding whether the SPV still has a function in a blockchain or smart contract environment, IC thinks that the SPV no longer has a role. But, he says, the SPV may have legal purposes similar to those of a notary. These legal control duties can be replaced with agreements in smart contracting, and when the information is transparent on the blockchain, the governance structure can be in an IT layer for a large part (C.TRANS,SMART). However, the legal aspect is far behind in these innovations. The law must change before such innovations can be implemented. If the law changes, many stakeholders will no longer be involved (C.LAWSEC,SPV).

Another question considered is the best way to innovate. Should the current system be copied and then fitted with a blockchain layer around it? Or should the whole system be replaced with a different idea? IC argues that the best way is to copy the current system first to prepare risk management and regulatory measures for the blockchain possibilities. Another way of doing it is not possible, because everything must change first before implementing these financial technologies (C.PRSECBL).

4.4 Interview D

This interview was held with a PwC manager from the risk assurance department, referred to as interviewee D (ID). This employee had worked at PwC for more than 7 years and did projects for several clients involved in securitisation processes. The interview lasted around 50 minutes and is transcribed in the interview appendix as Interview D.

4.4.1 Analysis

'What is the current status of the business process securitising mortgages and what opportunities could blockchain bring within the status quo?'

The interview began with a short introduction to a problem: 'The problem we have is [that] with an existing mortgage portfolio, a part or the whole portfolio must be sold to meet the new reaching regulations of Basel IV'. So a solution must be found for how to sell such a portfolio in the future, based on the blockchain technology. This portfolio of mortgages must be converted to cash, so the bank can lend more and boost its economic performance. The process now is to put a large package of mortgages into an SPV and sell the securities of the SPV to big institutional investors. The opportunity of blockchain technology is that these securities can be transformed into tokens. (D.TOKO). It is important that such securities also get more liquidity, so they are sold in smaller pieces (D.LIQ)

Managing the mortgage pool is also an important process that could be managed with smart contracts on the blockchain. In the current process, sometimes it is necessary to replace a mortgage that has been defaulted on with another one to keep up with the requirements of the investor (D.MMP).

'What are financial service institutions' requirements for a new RMBS business process based on blockchain technology?'

Swap providers protect the originator or the SPV from the changing interest forms. They can protect the mortgage incomes with a kind of insurance; they swap fixed interest rates to variable interest rates, or vice versa. ID said that this is not important for the business process of selling of mortgages (D.SWAP).

On the other hand, the function of an exchange is important, according to ID, as it is not possible to sell tokens back to the SPV. This is similar to buying stock from a company: it is not possible to sell a stock directly back to the company. To ensure trade and liquidity, an exchange is always needed in the process (D.EXCH).

ID pointed out that controls in the system were also important. It is important to develop a business process with the corresponding control framework. Risk must be defined before finding the controls. ID said that for every step, risk must be looked at, and then a control must be found for that risk. He also recommended looking for double controls, so that the control must be done one time for the whole process. Smart contracting could play a major role in preventing double controls (D.CONSEC).

'What would a new blockchain-based securitisation business process model look like?'

The interview also covered whether a token should be linked to an individual mortgage or to a package of mortgages. ID discouraged the idea of linking a token to an individual mortgage, because there would be too much risk for one financial product. He suggested that an SPV which has the value of the possessing mortgages must be sold in tokens. This is similar to the original idea where the SPV is sold as stocks called RMBS(D.TOKO).

According to ID, it is not necessary to have a lot of data on the tokens, because this data stream is not important for the selling of the loans. The only link that has to be made is the link between the loan and the borrower. It is also important to link the token to a certain value, such as the value of the loan, the collateral, or the average LTV of the mortgage pool (D.DATA).

4.4.2 Additional findings

ID made an important point about the process of paying interest and redemption in the system. In the current process, these yields are credit for the securities in the custodian application. With the token, it must be possible to credit the yields on the token. But it may also be possible to keep this money for the moment the token is sold. ID did not know the solution to this problem; it is something that must be researched (D.MONPAY). However, he suggested that

a token could work the same as a RMBS bond. But this process must be more efficient than it is currently. When the bond valuation is used, a calculation of the market rate must be included. The coin must decrease in value when market rates go up. This token would be less attractive for investors if it were bought with a fixed interest like a bond (D.BOND).

4.5 Interview E

This interview has been held with the a PwC Senior manager from the department Assurance. This employee is working already 11 years for PwC, he worked in Afrika, Australia, New York and now Amsterdam. He served most of his time for clients in in securitisation industry and banking. The interviewee is held anonymous and is called interviewee E (IE). The total length of the interview was around 65 minutes and is transcribed in the interview appendix as interview E.

4.5.1 Analysis

'What is the current status of the business process securitising mortgages and what opportunities could blockchain bring within the status quo?'

The aims of the securitisation process were discussed. IE said that customers are always looking for the cheapest loans. This can be achieved by keeping risk low, holding the number of defaults in a mortgage portfolio low (E.DEFBL), and decreasing the costs of the securitisation process itself (E. COST).

Managing a mortgage pool is an important process, according to IE. Many banks currently have a system that can track whether a customer has contractual defaults. When customers have arrears on their mortgage the are marked with red flags in the mortgage pool file. Red flags give the banks a sign that they must take action on that individual to receive most of the payments. They do not take those customers out of the pool but only flag them. Usually, only good customers with a good record qualify for a securitised recall (E.MMP).

'What are financial service institutions' requirements for a new RMBS business process based on blockchain technology?'

IE emphasised that controls are important requirements for banks, because banks must be prepared for anything that could be possibly go wrong in such a model. Banks must check for IT controls and payment controls. It is important to issue loans only to customers with a job and a good credit rating. Data input control is also important. If a customer claims to have a house in Amsterdam, for example, how does the bank know that it is really in Amsterdam? The SPV aspect is also important: the SPV must verify that it does not have double loans in its portfolio and that clients do not have two loans for one collateral. Mechanisms to protect data are important controls in order to protect it from crime or cyberattacks. Banks also must cover the risk inside the system (or commingling risk), such as when the originator goes bankrupt. People controls are also

important, including what kind of people the bank employs. The bank should aim to employ only smart employees with significant experience. (E.CONSEC)

Risk management is also important. MBSs are exposed to two types of risk, credit risk and market risk. The credit risk is the risk of the borrower not paying a mortgage, and market risk is dependent on the financial environment. In the Netherlands, market risk is not currently a problem because the economy is strong and house prices are high. However, investors are not interested only in financial products with low risk. There is also a market for high-risk products with high returns (E.RISKSEC).

IE pointed to the new accounting rule of IFRS 9. This forces banks to look at the future, and what their clients will pay. Before this rule, banks only had to look at data from the past, but they now must develop mechanisms that can look into the future (E.LAWSEC).

An important requirement is the interfacing problem of software. Banks work with many different software programs and applications, and different companies have different software and hardware. It is possible to create applications without this problem, but it is difficult to do so (E.REQBL).

'What would a new blockchain-based securitisation business process model look like?'

In creating a new MBS business process, one must take into account that some borrowers may pay on dates other than those in the mortgage agreement. Payments also arrive at different times, because different borrows have different pay dates from their job (E.CASH). Also, if a borrower loses their job, payment may be outstanding for several months.

Managing the mortgage pool is also important, according to IE. Some customers pay off their mortgage and some customers do not pay their mortgage at all. These must be replaced directly when such an event occurs to ensure the unaligned mortgage pool will cover the cash flow to the investor (E.MMP).

The value of a mortgage-backed security rises with house price. Currently in the Dutch market, home prices are soaring, which reduces risk and increases the price of the MBS. Regarding interest rates, the economy is currently soaring with low interest rates, and so these securities are attractive for investors. Market rates are also determining the value of the MBS. Furthermore, if many investors want to buy these securities, supply and demand also affects the value of the MBS (E.IWT).

4.5.2 Additional findings

IE also pointed out that the banks' future prediction models are also a type of control. These are based on the payment data of the customer. He gave an example with different types of debt:

'A house is a good example. If you have a credit card, if you have a normal car that you lease, and you have your mortgage, you have three types of debt. Typically . . . if [the customer] runs out of cash, he will first stop paying his credit card, and then he will stop paying his car, and then as a very last resort, he will stop paying his mortgage. So if he has some savings, it's going to take some

time to reach the point where a mortgage will not be repaid' (E.MMP,CONBL).'

If you have all this information you can create models that can predict the future. This can be build in as a control, so you can predict beforhand the default of the mortgages. These models are important to build in a securitisation business process.

4.6 Interview F

This interview was held with a strategy associate from PwC's strategy consulting department, referred to as interviewee F (IF). This employee had worked in this position for three years. He worked mostly clients in the banking industry and worked on some projects advising banks on blockchain. The interview was around 30 minutes long and is transcribed in the interview appendix as Interview F.

4.6.1 Analysis

'What is the current status of the business process securitising mortgages and what opportunities could blockchain bring within the status quo?

This topic was not discussed this interview.

'What are financial service institutions' requirements for a new RMBS business process based on blockchain technology?'

The capital requirements of Basel 4 and the solvency law for insurance companies play a large role. Banks must hold significantly more reserves for a mortgage than an insurance company, and therefore an insurance company can originate a mortgage much more cheaply per these regulations. But if the credit risk could be sold to the insurance company, banks could hold less capital reserves. This would be a solution to this problem (F.LAWSEC).

Another important fact is that banks must increase transparency on their viability, company and market risk. Blockchain could help make it easier for supervisors to perform checks on this type of data. (F.TRANS)

'What would a new blockchain-based securitisation business process model look like?'

FI argues that in such a new model, many stakeholders become redundant or have to change their way of working by implementing blockchain technology. For example, auditors will need to change their way of working but will be still be necessary. Their job becomes easier. Auditors must review the sale of securities. If such transaction are on the blockchain, this manual test work can be don automatically (F.AUDIT).

On the other hand, clearinghouses are stakeholders that become redundant. Their task is to do all of the paperwork and record the security transaction. However, this is no longer required if the transaction goes on a blockchain. This process of recording transactions is even slower when the transaction goes

international, because all of the accounts of the different banks must be verified. This process can take up to two days, but with blockchain, it could take only a few minutes (F.CLEAR).

Exchanges for trading securities will still be needed. In the case of blockchain implementation, these exchanges will need to change their way of operating. Technological change plays a large role for these exchanges. If they do not change, they will lose their function. This is why large exchanges have set up collaborations with blockchain exchanges to implement the technology (F.EXCH).

Custodian applications will also have to change the way they work. They are already looking for native crypto collaborations with start-ups to stay ahead of the technology. Custodians may be one of the stakeholders that become more important due to their role in preventing cyberattacks and keeping assets safe. Custodian companies will need to develop strong cybersecurity mechanism to protect the assets they store (F.CUSTO).

Credit rating agencies will also retain their function, according to IF. If securitisation happens more often for all of the different risk profiles, the credit ratings agencies have to rate the packages with securities. Smart contracting can perhaps standardise the rating process so that standard coins come with a standard contract. In that case, credit ratings will have less work to do. However, IF thinks that there will be a more customised kind of tokens, and the different tokens will need a credit rating. Credit rating companies also have the advantage of their brand. In the financial industry, investors look to see if products are approved by Moody's, Fitch, or S&P. If so, the products are more trustworthy for investors (F.CRAG).

To use the valuation of a bond to value a secutoken is a possibility, because normal MBSs are also traded in this way. However, the token also needs a risk factor. This way, a mortgage portfolio can be split into different kinds of tokens with different risk and return profiles. It may also be possible to sell tokens with different kinds of cash flows, such as from the first 10 years or from years 10–30 of a mortgage (F.BOND).

4.6.2 Additional findings

The interview also included the possibility of selling only the credit risk. This would be an advantage for a company that must hold capital reserves. This is thus more of a kind of insurance token. An investor gets a part of the interest rate, but when the collateral is gone or borrower gets bankrupt, the investor must take care of the debt (F.CREDIT).

When asked if transparency may hamper blockchain implementation because banks do not want to be transparent, IF said, 'If the information stays in the private network between banks and insurance companies, I do not see a problem'.

5 Business process model design

This chapter explains all of the empirical findings found in the interviews which were used to create a blockchain-based business process for securitisation. First, the interviewees often mentioned securitisation itself in order to give the researcher enough knowledge to uncover the issues in this business process. Therefore, the same designing tools are used for the existing process and for the blockchain-based process. Another reason to explain the current process is the lack of comprehensive information in the literature, which may be related to the notion of transparency. Transparency is still a restriction when research is done on business processes at large banks, especially securitisation. The analysis is built on three different designing tools: stakeholder analysis, root cause analysis and a BPMN, as already mentioned in the methodology. After the BPMN model from the current process is built and issues are addressed, a blockchain-based process is built to discover the improvements that blockchain can apply to this business process.

As mentioned above, it is difficult to find the proper information in the literature to give a clear view of the business process of securitisation, likely because transparency is still restricted when it comes to structured financial products and securitisation. It is also difficult to define one singular business process for when banks securitise loans into financial products because there are many variations. In this research, the securitisation transaction 'Purple Storm' from one of the largest banks in the Netherlands is used as the guideline for the current business process model. Other securitisation processed are also analysed but not used as guidelines because this project focusses on recent transactions in the Dutch securitisation market; the Purple Storm transaction was executed in 2016.

5.1 Stakeholder analysis

To gain a better understanding of the stakeholders involved, different securitisation transactions are analysed. As mentioned previously, the Purple Storm transaction is the chosen guideline for this research, but stakeholders may have different tasks from other securitisation transactions. If this is the case, the difference is noted and explained. In the Appendix B, a table of stakeholders is displayed with a short description of their responsibilities, their interests, the influence that changes in the business process may have on them, the impact these changes have on their own business model and their attitude about the implementation of blockchain. This section is meant to discuss the stakeholders more broadly to provide an understanding of their importance and the possibility of their elimination.

The first stakeholder is the *borrower*. This is the stakeholder at the start of the process. The borrower looks for funds to cover the cost of a home and seeks a mortgage issued by the originator. The interests of the borrower is to find the right mortgage for the lowest possible cost in order to fund the purchase of the home in a safe manner. Advice about transparent conditions is also in the interest of the borrower. The borrower's influence on the way the mortgage is funded is quite low in the current system. The impact on this role from the introduction of blockchain may be high because costs can lessen while transparency increases. When transparency increases, it adds stability to the

financial system and reduces the chance of a financial crisis that causes defaults by borrowers. The attitude of the borrower is not applicable as it falls outside the scope of this research.

The *originator* is the party that provides mortgages to borrowers. They fund mortgages in many ways, as discussed in the literature review. The largest originators in the Netherlands are Rabobank, ING, ABN AMRO and Aegon. These financial institutions must meet the terms of the capital requirements directive from the European Commission and meet financial laws (WFT). They have high interest in the benefits of blockchain, especially for lowering costs and automating manual processes. However, they may face a challenge, as more transparency may hamper the blockchain implementation by creating more demand for difficult information on securitisation to be clarified and coherent. This can take a lot of effort for the designated parties involved. Policies must require those financial institutions to be transparent in order to increase financial stability, which is the intention of MiFit and the Basel Accords discussed in the literature review. Another important interest driver is the possibility of reducing prepayment risk by introducing smart contracts and liquidity risks by decreasing the size of saleable debt. This chance may have a high impact on the originator in a positive way, so the influence on the originator's attitude will be large because these parties are the source of the funds of the transactions. In the Purple Storm transaction, Obvion NV was the originator (Alderotti and Thakur 2016, but this is a mortgage branch of Rabobank.

The *arranger* has a large responsibility when establishing a securitisation transaction. The arranger has many management tasks and is responsible for bringing together all parties involved in that transaction. In the Purple Storm transaction, Rabobank together with JP Morgan fulfilled the role of arranger, with Rabobank as lead arranger and JP Morgan as secondary arranger. Rabobank is also the bank that sells off the mortgages, which is one of many double tasks for the main stakeholder in this transaction. JP Morgan can be seen as an assisting party whose cooperation results in another expensive fee. The Rabobank, as lead arranger, has a positive attitude to the reformation of the business process, but the assisting party fulfilled by JP Morgan may fade away with implementation of blockchain securitisation technology; they are an intermediary that can be replaced by a blockchain application or platform. The impact on this intermediary will be high and negative, and therefore the attitude toward blockchain implementation is negative.

A *special purpose vehicle (SPV)* is a subsidiary company that is mostly established by the arranger and transfers the loans of the originator. With this transfer, the originator sells off the mortgages to the SPV, and from that moment on, the loans are no longer on the balance sheet of the originator. Financial risk is also transferred, and the legal status and the asset/liability structure makes the SPV's financial obligations secure, even if the parent company (Rabobank, in case of Purple Storm) files for bankruptcy. The influence of the SPV is low because it is created by the arranger as a subsidiary company, but the impact will be high on companies as SPVs. In particular, these registration and administration tasks can be done by blockchain applications, but due to legalities, it will be a long time before SPVs are redundant.

The *security trustee* is the legal branch of the SPV that hold security over the rights of the investor. The employee of Intertrust said that the most important task of the security trusty was to enforce security when needed and calculating

the interest and redemption payments for the investor. From there the payments are send to the paying agent who is responsible to distribute the payments to the security holders. The influence, impact and attitude of the security trustee are the same as the SPV, as party also holds a legal status. Laws would have to change for this party to become redundant.

A *swap counter-party* will take over risk exposure during the return of premiums. Mostly, swap counter-parties are used to swap variable interest rates to fixed interest rates. Investors must pay out against a certain fixed rate, but mortgage interest payments often differ for each mortgage. With a swap counter-party, it is possible to create the appropriate portfolio of mortgages to pay a certain fixed amount to the investors. A swap counter-party has low influence on the system but remains necessary for creating portfolios with certain financial instruments in order to level interest payments to the preferences of the market. In the Purple Storm transaction, Obvion N.V., which was also the originator, was the swap counter-party; the company took the interest risk itself, but in other transactions, it can go to an external party as well.

The *paying agent* is the intermediary between the SPV and the investor. They recalculation after the calculation of the security trustee and distribute the payments to the security holders. If the calculation are not matching with each other the paying agent will discuss this with the security trustee, who can take steps to enforce the security of the payments when needed. They get administration fees and transaction fees for their work. Their influence is low in the business process, but in blockchain smart contracting will have high impact on their profitability. Smart-contracts can make their work redundant by executing pre-arranged agreements.

With interviewee A and F a discussion was raised about the *clearing systems*. Interviewee A told that clearing systems still use a lot of manual processes to process transactions. These systems are used by the paying agent, to distribute the interest and redemption payments. These payments are transferred to the custodian applications of all the investors in possession of the securities. Interviewee F, said that the impact on the clearing systems would be high, because these processes are done by the blockchain. This kind of organization will not survive when blockchain will play a role in this process, thereby the negative attitude.

The *custodian* is a company to secure the safety of the securities of an investor. The interest and redemption payments of bonds are also transferred to the location of that security. This is most of the time the custodian application. The custodian application is an important stakeholder in the process because of the safety of the securities. They are also needed when securities change to tokens. Nevertheless, they need to participate in the blockchain transformation to gain sustainable profits. The impact of the blockchain-based model will be medium when they innovate their IT systems.

In a securitisation transactions, there is a *servicer* involved. A servicer ensures the on-time payment of interest and redemption. In the Purple Storm transaction, Rabobank was the servicer itself because it already owned the payment data. However, sometimes an originator hires an external party to take over these payments. The interests of the servicer are the fees from collaborating parties. The influence is again low, but the impact on them of blockchain's implementation will be highly negative.

Credit rating agencies will rate the creditworthiness of the SPV and the

products that they sell. In the Purple Storm transaction, ratings are given by all three credit rating agencies, Moody's, S&P and Fitch. In fact, smart contracts can take over these tasks to give ratings to financial products if requirements are clearly defined. In all likelihood, those three credit rating agencies have so much power over rating practices that they could slow down blockchain developments. They are not expected to support progressions that disrupt their business model.

The responsibility of the *Broker* is to search for a deal. It is common that they are looking for buyers when selling parties want to sell their products, but it may also be the other way around. These parties also look for investment products for customers if they have certain requirements. This advisory role is not expected to soon become superfluous, particularly with all of the international markets nowadays.

The *institutional investor* are mostly large pension funds looking for safe investments to earn profit on the money they invest. Investors have a lot of influence on the implementation of blockchain; if investors do not trust the products, they will not invest in them. This same theory applies also for the ICT architecture behind the investing products: this architecture must ensure that the investments are safe and secure. The impact on institutional investors is high because they will benefit from all of the blockchain advantages, including lower transaction costs, increased information transparency and symmetry and reduced liquidity risks. This is why investors have a positive attitude toward blockchain.

Regulators like the European Commission and the Dutch government provide laws and policies to stabilise the economy and maintain fair trade. They also implement and enforce the safe and transparent investment environment. By creating laws and policies, their influence is high. However, a technological change will not greatly impact this stakeholder, and therefore they will not cooperate with innovating this ICT architecture; at least, they may offer innovation space for testing, which is what they do in England by FCA Sandbox, as noted in the interview with Intertrust.

Supervisors such as the AFM and the DNB carrying out controls if financial institutions are complied by international and national law. These stakeholders are able to enforce with significant fines, lawsuits and even the withdrawal of permits when financial institutions violate laws.

Auditors carry out controls to ensure financial institutions meet their obligations to regulators and investors. All of the parties in the securitisation process need to be checked by auditors, which creates many expensive fees. If intermediaries can be cut out of the business process, the fees for auditors will also reduce. Nevertheless, auditors have positive attitude toward the blockchain transformation, which emerged from the interviews with all of the people of PwC. For completeness, *Tax advisers* and *Legal advisors* are discussed as well. Both parties have an advisory role in this business process, so their interests are based on the expensive fees that they earn with their work. Unfortunately, those two parties lay beyond the scoop of this research and are therefore not further discussed.

5.2 Blockchain-based stakeholder analysis

In this section, the stakeholders in a blockchain-based process are discussed, though some of these stakeholders are excluded from discussion as they maintain

their previous positions and tasks. Consequently, only the new stakeholders and the adjustments from the current process are sketched to demonstrate the new stakeholder perspective.

First, interviewee A spoke about a blockchain application for the issuance of an RMBS . The interviewee explained the outdated process of trading securities, from the SPV to the investor. In the current process this is still be done through email and pdf documents. The payment methods of choice on the securities were discussed and recommended for a blockchain or smart contract application. In interview C, the interviewee spoke about the elimination of the SPV and offered a solution to trade tokens, 'the new securities', directly between the originator and the investor. He considered this to be a worthy solution to reduce transaction costs in the securitisation process. In interview D, it was proposed to maintain the SPV and distribute tokens between the SPV and investor. Overall, the interviewees agreed that when removing the SPV, transaction speeds increase and the costs involved in a securitisation transaction decrease. The sole reason to maintain the SPV in the business processes should be for legality. However, in the most ideal situation, the SPV is removed from the process, which also means an elimination of the security trustee because this is a branch organisation of the SPV.

Interview F, however, the interviewee discussed a legal purpose of the security trustee, which is to guarantee the redemption and interest payments to the investor; this could potentially also be done with a smart contract. For the most ideal situation, the security trustee is eliminated to reduce transaction costs, though the legal purpose of the paying agent may be a hindrance to removing this stakeholder in the foreseeable future. First smart contracts must become legally enforceable to meet the functions of the the security trustee.

In all of the interviews, the notion arose of how smart contracts could change the way investors receive interest and redemption. If smart contract are used for the distribution of payments in this system then the paying agent becomes redundant.

In interview A, the arranger was explained; this stakeholder is the lead manager of the securitisation transaction or the bank that takes the lead in the transaction. This role is primarily played by major investment banks, like JP Morgan in the Purple Storm transaction. Interview C brought up the topic of a token that is distributed by a kind of initial coin offering (ICO), or an issuance event from the security. An ICO typically stems from a start-up business to acquire funds for the further development of their product. This proposed ICO would be setup by the start-up themselves and a token platform like Ethereum. To offer or issue a self-made coin, it is necessary to create a decentralised application on the Ethereum blockchain. Offering mortgage tokens is precisely the type of transaction for which this platform is intended. The arranger in this process is a platform like Ethereum, which could also be the case in the proposed scenario of this research. The arranger may transform into an IT platform or company to provide the smart contracts and the possible tokens, and this role will be the IT blockchain specialist in the middle of the transaction. In the second stakeholder analysis of the blockchain-based securitisation process in Appendix B.2, , this stakeholder is included as a new stakeholder. It is not certain whether the arranger should transform into the new stakeholder, as this role could also be a disrupting company that can provide these services, with the Ethereum platform as precursor.

The servicer is also removed from the business process in the ideal situation. In some cases, there already is no servicer in the normal business process. In the new blockchain-based process, the originator and the smart contract specialist manage of the tasks of the servicer because the smart contract specialist takes the mortgage data of the originator and develops the blockchain solution.

If a blockchain based solution will be introduced the custodian has to transform their activities based on a blockchain application. Through the ongoing cybercrime attempts on the crypto exchanges (Neuron 2018), storage of cryptocurrencies is of growing importance in the world of digital assets. Therefore, everyone who trades these assets removes them from the exchanges directly after trades and stores them in their online or offline wallet. Online wallets are mostly held by custodian companies like myetherwallet.com or, when there is doubt about the security of these companies, an offline hardware wallet such as the nano S is also a solution to keep digital assets secure. Many large custodian companies already try to transform to online custodian platforms by acquire and enter into collaborations with crypto-native custodian companies(F.CUSTO).

Finally, the dealer or broker is not needed anymore to bring buyer and seller to each other, this activity will be taken over by the token exchange in which the mortgage tokens are tradable. This option was discussed in interview C. Nevertheless investment advise is not expected to soon become superfluous, particularly with all of the international markets nowadays. This market is a platform such as Bittrex, Bitfinex or Bitstamp (cryptocurrency exchanges). In the most ideal situation, which we assume, the market platform on which these tokens are traded is accessible to everyone increase the liquidity of the secutokens.

5.3 Root cause analysis

By identifying the root causes, a better understanding of the issues of designing a new business process model can be gained, which in turn helps to create improvements. The root cause analysis is visualised in a fishbone diagram, and it was chosen to elaborate two fishbone diagrams; the first one represents the current state of the securitisation business process model and the second one explains a blockchain-based business process. These two fishbone diagrams are included in Appendix C.1 and C.2. The main goal of the fishbone diagrams is to create a constructive technology assessment and determine the factors that influence the design of the business process model. When these direct influences are not properly investigated, the final design can include errors that can no longer be solved at a later stage (Pesch 2015). To avoid this situation, the main contributions to the design phase are evaluated. In the interviews, three recurring topics were deemed to be important: governance, stakeholders and technology. To more closely address these subjects, individual analyses are explained below. These analyses provide more insight into the core influences in designing the business process model.

5.3.1 Governance

Governance is the first influence in the design, and it is divided into three secondary factors, which must be considered before designing the business process model. One of these secondary factors is ‘Wet financieel toezicht’, which is the

law that provides supervision to financial institutions in the Netherlands; it is maintained by de Netherlands Bank (DNB) and the Netherlands Authority of the Financial Markets (AFM) (LAWSEC.A). It guaranties reliability, expertise, financial security, adequate and honest business management, a duty of care for customers and transparency, as elaborated in the literature review. These characteristics are essential in the current situation but also must be maintained when designing the new business process model. In the second factor, a party that influences the design is the European Commission, which has developed several different policies (LAWSEC.A.B.C). The capital requirements directives is based on the Basel Accord, which is renewed after certain periods of time; it began with Basel one, and the fourth version is now in process. The most important target of the Basel Accord is to minimise risks in the banking sector to prevent another financial crisis. Those risk-preventing policies affect the design of the ICT architecture, and a transparent design could help regulators to check banks' compliance with the agreed policies. Important factors such as capital requirements, leverage ratios and measures for risk profiles could be verified more easily if they are visible to everyone or to agreed-upon parties. Transparency is also one of the main focus areas of the Markets in Financial Instruments Directive in trading derivatives. Regulators must make prices more transparent before trades occur, which was not the case before this policy. Previously, a broker had no duty to be transparent about the prices and choice of exchange when issuing the securities of the investor. This lack of transparency raised suspicions by regulators that it benefitted the intermediaries, not the end investor. The General Data Protection Regulation (GDPR) and Payment Service Directive 2 (PSD2) have also influenced the process design: for GDPR (LAWSEC.C), the ways that personal information must be kept private have shifted, while PSD2 dictates how to distribute client information between financial institutions to simplify the process for innovating parties that need the data to make their applications work. The last secondary influence of governance are the controls (CONSEC.D). Controls, like the two other secondary influences, are applicable to both the old and new systems. The controls are divided into five categories: governance controls, data controls, change management controls, internal controls and IT general controls (PWC 2018). Governance controls keep track of business structures and continuity while monitoring the activities taken to achieve the goals of the organisation. Data controls ensure valid data inputs, guarantee data quality and prevent data loss or leakage. Change management, in the case of a blockchain application, is more complex than in the current situation. The literature discusses the difficulty of overwriting information on the blockchain because each subsequent block validates the information in the blocks before. Especially in case of using inflexible smart contracts, the risk of incorrect or malfunctioning smart contracts must be minimised by means of controls. Internal controls check if the organisation or business process is compliant with relevant laws, legislations and policies while optimising the effectiveness and efficiency of an organisations' objectives. Repeated assurance reports are also part of internal controls. The last category of the controls is IT general. These control logical access management to the systems, maintain physical and network security and provide backup when data is lost by corruption or failure. In the interviews, much was spoken about the laws, policies and controls, which demonstrates the important influence that these factors have on the design of the business process.

5.3.2 Stakeholders

In the fishbone analysis of the current situation, many more stakeholders influence the current business process than the blockchain-based process. It is not necessary to again elaborate these stakeholders' roles, as it is done in the stakeholder analysis. However, it is also not possible to exclude these roles from the fishbone analysis because they are important to the design of the new blockchain-based business process.

5.3.3 Technology

A blockchain network is hardly to compare with the current ICT architecture from financial institutions. The technology used to organise securitisation transactions consists currently of many separate IT components. To give an example, a financial institutions uses different soft- and hardware to record transactions then for preventing cyber attacks. A blockchain network is able to replace this component system for a more solid one. A blockchain network is able to bring these separate components in a distributed network. By a large community of nodes and a proper consensus mechanism, the blockchain is almost impenetrable for malicious parties. Unfortunately, many banks creating private and premissioned blockchain networks to create a safe environment for their data. But with less users, thus less verifying nodes in the network, their is just a bigger change of manipulation on the data. In a public blockchain, precisely that independent user or institution that take part in the verification is the security feature of a blockchain. These users are still needed to use the full potential of the blockchain and create a secure decentralised chain. Nevertheless, a private premissioned blockchain have their advantages. From the interviews it became clear that may these advantages may more fit to the business model of financial institutions. These commercial institutions are looking for structural improvement to make their business processes more efficient. They are not looking for a solution were they loose control over their own business process and building a power game based on computational power. With a private or consortium blockchain a power game with outsiders is prevented by keeping the network small, and only allow parties to the network that have been approved in advance. The data and rules of the blockchain in this network can be easily modified to maintain authority in the network. To prevent manipulation in this kind of systems a proper consensus mechanism must be obtained were all the parties first have to control each other to allow changes in the network. By this modifying character of the network, networks with a smaller block size could be build. This block size reduce the needed computational power to resolve and validate these blocks. This can lead to much faster transactions and less energy consumption which suits better by the character of financial institutions.

5.4 BPMN securitisation business process

In this section, a BPMN model of the current business process for securitisation is explained. The knowledge for this design was gained from the interviews and the literature that was studied. On the basis of the current BPMN model, literature and expert interviews, a future-proof blockchain-based model was created. In the interviews, sub-processes that could be innovated were discussed,

which resulted in three sub-processes in the current business process model that must be improved for the future model. The first sub-process is the way RMBSs are created and how these securities are brought to the market. The second sub-process that must be improved is the way that payments must be made to investors when they own the securities. The last sub-process is the default management process. When applying blockchain applications to these three sub-processes, the sub-processes are further subdivided into five areas to explain them in a more detailed way.

5.4.1 Overview process

The first BPMN model is an overview of the entire business process. In this business process, the three sub-processes are indicated with an orange line and a letter. These processes were chosen for optimisation on the basis of the interviews. In interview D, the interviewee created a drawing with the problem of the current securitisation process. In this drawing, the cashflow indicated is with 'lening + periodieke euro's' and '1 malig euro's betalen aan originator', which refers to B in the overview . The words 'marktplaats and beurs and verhandelen' plus the distribution of coins refer to the innovation of process A in the overview. In all of the interviews, the topic of managing defaults arose because a default can ruin the securitisation process. If there are too many defaults, a financial crisis may occur, as happened in 2008. In interviews C and E (C.E.DEFBL), the interviewees spoke at length about defaults, especially that they could be easier to manage if they are noticeable with smart contracts. This sub-process is indicated with the letter C. The rest of the securitisation process is not in the scope of the research because of the scale of this business process.

The process starts with a borrower who requests a mortgage to buy a home. This mortgage request is in itself already a vast business process done by the originator (ING, Rabobank, ABN-AMRO, AEGON etc.), but it falls outside the scope of this research. The mortgage is pooled by the originator in a mortgage pool. This pool is a data file with all different mortgages that must be sold to the SPV (set up by the originator) to relieve the balance sheet of the originator and transfer credit risk so they meet the capital requirements of the Basel Accord. When the balance sheet of the originator is relieved, the business process of originating mortgages can continue. When these mortgages are transferred to the SPV, the mortgage pool is converted to a saleable investment product in cooperation with a rating agency that validates the investment products. From there, the securities are brought to the market by the SPV, were clearing houses and exchanges facilitate the exchange of the security transactions (A.G.CLEAR). In this sub-process, the cash flow from investor to SPV is given. The investor buys the securities from the market, often with the help of a broker (VA.BROKER). Process B is the monthly cashflow from the borrower to the investor, and this cashflow consists of interest and redemption payments. These payments are passed by the originator, and commingling risk appears through the blend of money at the balance sheet of the originator (VA.COMMING). From here, originators carry out controls on the separate cash flows in their organisations to guarantee the payments to the investors. Thereafter, the payments are passed to the SPV, and then several of other intermediaries interact with the payments before it arrives to the investor. In the next section, the three main processes are explained in detail.

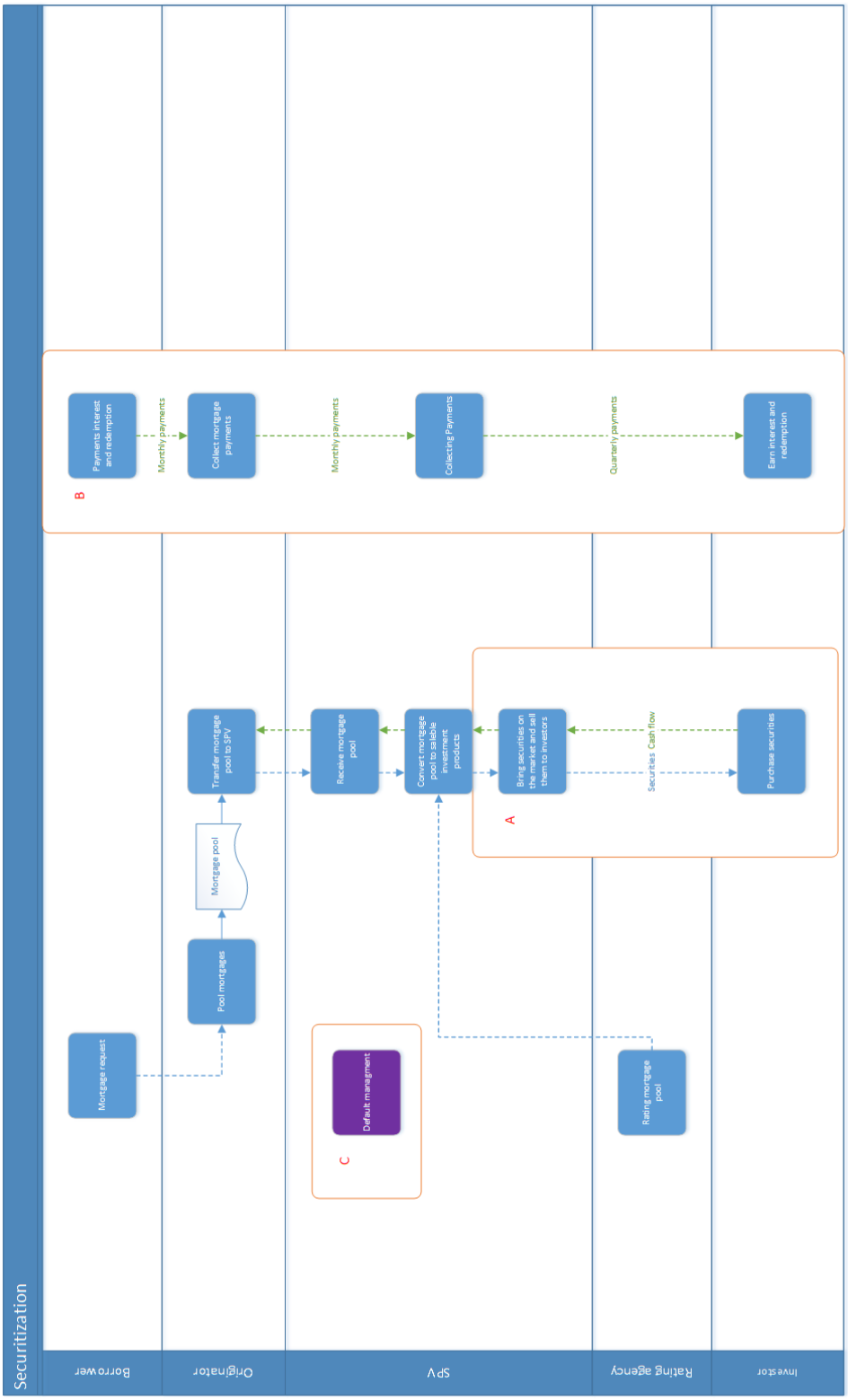


Figure 15: Securitisation overview

5.4.2 Buy residential mortgage-backed securities

Buy RMBS is displayed in Appendix D.1 and indicated in the overview with B. The way RMBSs are bought in the Netherlands is through an over-the-counter buying process (C.VA.TRADSEC). In this process, at least six stakeholders are important. The buyer in this process is a large institutional investor, mostly insurance companies or pension funds. The seller is the originator of the mortgages. Most of the time, those two parties are brought together by a broker. Sometimes, investors are sought before the transaction, which is also done by an intermediary. In this research, the most common trade principle, were buyer and seller find one another using a broker, is applied. Three other stakeholders are needed to finally settle the trade, but these three take over the back-end side. These stakeholders are the trade application or exchange were the securities are presented, the custodian application were the securities are stored when bought and the clearing house, which is responsible for the transactions and the records. The controls given by R.1, R.2, R.3 and R.4 control the accuracy of the payment, completeness of the payment and if the payment is processed on time, along with a four-eye control to validate data (VA.CONSEC). In interview VA, the controls in this process were mentioned, but the interviewee thought it would impossible to explore all of the controls in the system for a research of this size. He proposed an explanation of the main controls of the system but to not discuss them further in terms of the blockchain because, in this research, it is important to focus on the structure of the business process and how to make it more efficient with blockchain; the interviewee suggested that the controls of the full system could be a study on their own. Following the interviewee, the three main controls must be executed every time data is transferred to another stakeholder.

In the second BPMN model, indicated with an A and called 'Buy a RMBS over the counter', how a deal is settled is displayed. The buyer and the seller use the broker to find each other. The investor (buyer) requests that the broker finds an appropriate investment to meet the buyer's requirements. The seller find a broker to issue securities. The broker is then able to match this request with the issued securities in the database. If request and the securities are matched, the offer is sent to the investor, and the investor can decide whether to accept the offer. If the offer is declined, the broker searches for a new offer; if the officer is accepted, then it is sent to the seller. This process only happens in over-the-counter trades; in case of a normal trade, the deal is settled when the investor confirms. If the seller also confirms in this case, then the deal is settled. After the trade is settled, the clearing systems transfers the assets and ensures that the assets arrive at the custodian. The problem with these over-the-counter trades is that only large investments firms can take part in these transactions. These RMBS products are only sold in such large packages that they cannot be bought by other parties who may be looking for this kind of investment instrument. If those products could be sold on exchanges to other parties in smaller amounts, it could open up a new market (A.C.PACK).

5.4.3 RMBS payments

In the payment process (indicated in the overview with B and in Appendix D.2), there are six important stakeholders who pass on the funds: three main

controls for the calculation of the payment and three for the control of the payment. In the document of Purple Storm from S&P Global (Alderotti and Thakur 2016), the common risk of the payment transfer in the payment process is commingling risk; for originators, it is important to execute controls and separate cash flows enough to reduce this risk. This risk does not have a role for the other intermediaries (VB.RISKSEC).

The process starts at the originator, who calculates the payable for every customer with a mortgage. In this step, it is important to execute the aforementioned controls. Then, the originator sends the payable to the borrower, and this payable is often paid automatically with a direct debit payment. Still, this payment can be refused by the borrower. When this happens, the payable goes into the mortgage default process, as indicated with A. When the borrower pays the payable on time, the payment process continues as it should, such that the payments are controlled at the balance sheet of the originator. The next two stakeholders, the SPV and the paying agent, go through the same steps: first, they calculate the payable and send these payable to the payee. In the case of the SPV, the payable is called the loan tape; this is not a payment of one mortgage, but the payment of the mortgage pool. These payments are checked by the payee and paid if the controls validate the payment. No commingling risk is present for the SPV and the paying agent because payments are not combined with other funds. This risk only exists for the originator (Bank)(VB.RISKSEC). Although the steps in the process for the SPV and the paying agent are the same, the functions of the SPV and the paying agent are very different. The SPV is established by the originator to overtake the liabilities of the originator and address the balance sheet. It also isolates financial risk to protect the originator against loan defaults and bankruptcy of the SPV. The paying agent controls and distributes the payments of the SPV for the clearing systems and the investors. After the paying agent checks the payments of the SPV, they create a distribution report for the clearing systems (VB.PAY). These payments are made to the outstanding securities and registered in the custodian application. From there, the investor is able to check whether payments have been made to his financial products.

5.4.4 Mortgage default

The process of the BPMN model 'Mortgage default' included in D.3 begins in the RMBS payment model in D.2 because a mortgage default is the cause of a mortgage not being paid on time or not at all. In the path of the borrower in the model RMBS payments, there is a gateway (pay monthly interest and redemption payable) if the borrower does not pay the payment and redemption. The arrow goes to the off-page reference A, which is linked to the model mortgage default. The A point then starts at the borrower, but by A's action, the originator registers the arrears of the borrower. First, the originator tries to find a payment solution by contacting the borrower. If this solution is found, the model points back to the RMBS payment model so that payments can be resumed, and with a payment arrangement, if needed. If there is no solution found, the mortgage default process continues, which means that the arrears data is sent to the debt management of the originator and the SPV. Consequently, the SPV can prepare the re-valuation of the securities. If the payment data is sent to the debtor management, a collateral auction is prepared and

executed. The residual debt is then repaid, and the remaining is paid to the SPV to compensate the SPV for the missed interest. When these leftovers are sent to the SPV, the securities get re-valuated as loss for the investor that holds the RMBS of the SPV.

5.5 BPMN blockchain based securitisation business process

This research attempts to find a more efficient process for the securitisation based on blockchain technology. The aforementioned models of the current process act as the foundation on which to construct a potential blockchain implementation in the securitisation process. The models in which blockchain is implemented were also built with the help of the BPMN. The current process consists of three models; by implementing blockchain, two additional processes that deserve more attention were discovered, so the blockchain-based process now consists of five models. The new models are 'tokenising mortgages' and 'secutoken storage'. These two models receive special attention because tokenising of mortgages is a new concept for converting mortgages into an investment instrument: the secutoken (security token). Furthermore, the storage of tokens explain the different way that debt papers, stocks or bonds are stored now. To design these models different trade-offs are made. These trade-offs are elaborated in the following sections, to summarise this information a trade-off table is displayed in the Appendix F The first column indicates the process the second describes the model design decision and the other two describe shortly the supporting data were the decisions are based on (interview data and literature data).

5.5.1 Tokenizing the mortgagepool

The three stakeholders, the SPV (C.SPV), paying agent (CASH) and clearing systems (clearing house) (F.CLEAR), could be eliminated with the introduction of blockchain and smart contract application. The SPV could be excluded if the mortgages of the originator can be tokenised. The tokenisation process transforms the individual mortgages or a mortgage pool into tokens using a smart contract, and the tokens could then be sold to investors (C.TOKO). Transforming data such as a mortgage pool into tokens can be obtained with a smart contract on the Ethereum blockchain (Buterin et al. 2013). A smart contract immutable after it is created (DutchBlockchainCoalition 2017), this function would eliminate a controlling party like the paying agent (CASH, PAYA). Furthermore, transparency of the blockchain makes it is possible to trace the tokens to investors accounts. This function could eliminate the distributing task of the clearing systems (F.CLEAR), because payments could be made automatically to the investors when the borrowers pay their interest and redemption. In this entire payment process, many controls (by auditors) and transactions (by administrators) are processed by hand, so using blockchain could finally speed up and decrease costs to automate these processes (Baron 2017)(HAND). In a redesigned process two important stakeholders are presented in Figure 16, the originator and the new smart contract specialist. The smart contract which is also displayed in the figure, is not a stakeholder but a supplemental entity that is used to tokenise the mortgages into secutokens.

In the process, there is a need to load off the balance sheet of the originator. Thereby, the originator establishes requirements for the smart contract. These requirements are, for example, the interest and risk profiles of the tokens. The requirements are logically linked to the mortgage data to create a decent investing product. When the smart contract specialist receives these data, the smart contract is created based on the requirements and mortgage data of the originator. If the originator approves the contract it is ready to be executed on the blockchain. Then, when the smart contract is executed, the secutokens are on the blockchain but still in the possession of the originator. It is the originator's duty to offer the secutokens on the token exchange. The off-page reference refers to the second model, 'secutoken trading', when the tokens are issued. In this process the rating agency has also no responsibility anymore, because the investor is able to identify from which mortgages his secutoken is build of. The investor is capable to criticise and value his investment himself (CRAG). Controls are executed by the originator and the smart contract. Yellow circles stand for automated controls and only R.1 and R.3 are executed, because in this process time does not play an essential role.

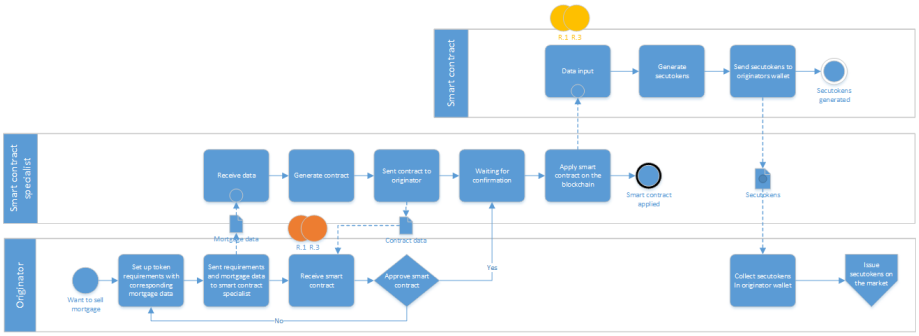


Figure 16: Tokenising the mortgage pool

5.5.2 Secutoken trading

This process is a continuation of the tokenisation process of mortgages. In this process, the broker is eliminated because there is no intermediary needed anymore to take care of over-the-counter trades. OTC trades are still possible but happen on the blockchain peer-to-peer, most of the trades will be executed on the exchange to reach a wider spectrum of investors (EXCH, LIQ). From discussion VA, it arose that the broker or investment bank is the person who brings buyer and seller together. Now, in the blockchain process all of the tokens are on the exchange for sale, this is now the most common place where the buyer meets the seller. Buyers or sellers are still sometimes in need of buying or selling advice, but this advice can also be given by an independent expert with knowledge of the investment products on the exchange. The trade application in the ''buy RMBS model" offers space for the token exchange, an application in which investment products are displayed. However, at the token exchange, secutokens are also traded and settled on the blockchain (Mori 2016), which is why clearing houses lose their place in the blockchain process (F.CLEAR). The only stakeholders that remain are the originator, token exchange and the

investor. This redesign of the trading process of securities to a trading process of tokens is based on the existing token trading platforms Bittrex, Bitfinex and Bitstamp. These staps have to be taken when tokens are traded on the existing trading platforms. See Figure 17 for the new BPMN model.

When tokens are sent to the token exchange by the originator, they are displayed to the market for sale. An investor is able to look at the database (on the website) of the exchange for an appropriate investment. On the website, the investor can place an order to buy a secutoken that is available in the token exchange database. When the investor places an order, the token exchange looks at the database to determine whether the secutoken is still available and if the funds on the account of the investor are sufficient to by the secutokens. The token exchange then sends a payment confirmation if the tokens are still available. When the payment is confirmed by the investor, then the trade is settled. Regardless of the payment instrument (ether, bitcoin or euro's), the money is converted into the secutokens. These tokens are credit on the account of the investor at the exchange. The funds are credit on the account of the originator, thereafter, the originator can withdraw his funds from the exchange. Controls R.1, R.2 and R.3 are executed two times in the BPMN model. By investor and the token exchange because here takes place data transfer and this investment data verified (CONBL).

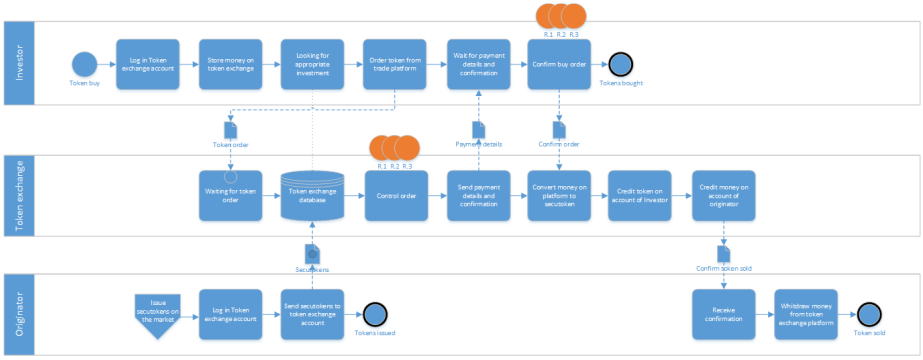


Figure 17: Trading

5.5.3 Secutoken storage

In this BPMN model, the online custodian application was chosen above the offline wallet because large current custodian companies that hold securities now are in a active transformation cause they can store crypto investments (F.CUSTO). If there was chosen for a offline wallet, all institutional investors had to keep their own investments safe. This task is to risky for institutional investors in a environment with so much cyber crime. Furthermore, it reduce their focus on making investments. In interview F is discussed that there will arise crypto native custodian companies when blockchain is being introduced.

The aim of this process, as displayed in Figure 18 is to transfer the token from the exchange account to the custodian application. The investor has to log into a token exchange account and then request a transfer to the custodian application. This request is completed by putting in the amount of tokens that

is to be transferred and the address of the custodian wallet were the tokens must go. The digital address and number of coins are then verified by the token exchange and, if all of this information is valid, the exchange sends a confirmation to the investor to confirm and check the transfer. If it is confirmed, then the tokens are sent to the custodian application in the custodian wallet of the investor. The investor can check the custodian account to ensure that the tokens were received. When the investor wants to sell the tokens later on, they must be transferred back to the exchange. The main controls that are executed are R.1, R.2 and R.3. The investor has to do these controls itself, if the right amount of tokens also end up in his online wallet in time. At the token exchange these same controls have to be executed to check if the investor is credible enough on the account of the exchange, and if the right amount is sent to the custodian application.

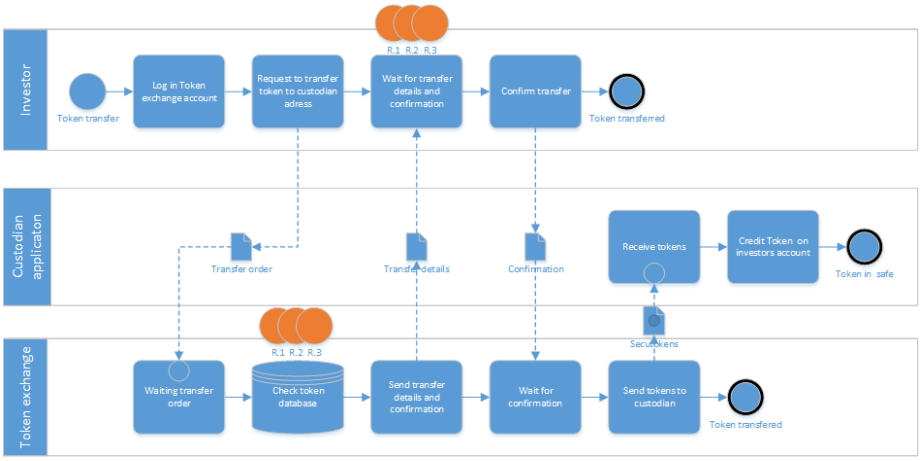


Figure 18: Storage

5.5.4 Secutoken payments

In the payment process based on blockchain, three important stakeholders are eliminated, as discussed in Section 5.5.1. There still remains one significant problem with the payment process based on blockchain, discussed in the last validation discussion VD: smart contracts on the Ethereum blockchain or other blockchain platforms not function with fiat currency. Smart contacts executed on one particular blockchain work with its corresponding cryptocurrency, so smart contract on the Ethereum blockchain work with the ether cryptocurrency, and the NEO blockchain with the NEO cryptocurrency. While these coins still exhibit enormous value changes, people still resist paying with these cryptocurrencies. A solution for this problem could be an exchange function built in the IT architecture that converts, for example, ether to euros. In that case, an exchange rate risk arises, and this risk has to be taken by the bank, custodian or investor, dependent on the strategy that is used to overcome this risk. These strategies (Spot rate, hedge, currency swap) are out of scope of this research but are a possible solution on this problem. Though, we assume the most ideal situation: every person involved uses the cryptocurrency that is used

for this blockchain (VD.MONPAY).

In that case, the process starts at the borrower with an interest and redemption payment. If the borrower does not pay the interest and redemption, then the payment enters the default process (CASH). However, if he does, then the payment is stored and controlled in the smart contract. If the smart contract agrees on the payments in terms of time and amount, then the contract distributes the payments automatically to the investors. Thereafter, the payments are also automatically sent to the wallet or custodian application of the investor. This can be done by the smart contract because it knows in which wallet the secutokens are located. The researcher proposes that the interest payments are made with the technology of the NEO platform. The interest payments can made to the investor following the NEO and GAS token approach. The platform NEO provide the NEO token owners with dividends (read interest) paid out in the GAS token. The amount of GAS the owner of the NEO token gets, is dependent on the duration the investor is in possession of the NEO token (Zhang and Hongfei 2018). This principle can also be used to pay interest payments in this new blockchain-based business process. Also in this separate process the smart contract replaces many of the payment controls that the SPV and paying agent normally manage, these stakeholders become redundant in the blockchain process. The clearing houses that take care of all of the transactions are redundant too because the payments operate over the blockchain (F.A.CLEAR). Controls if the borrower pays the full amount at the right time are automatically done by the smart contract.

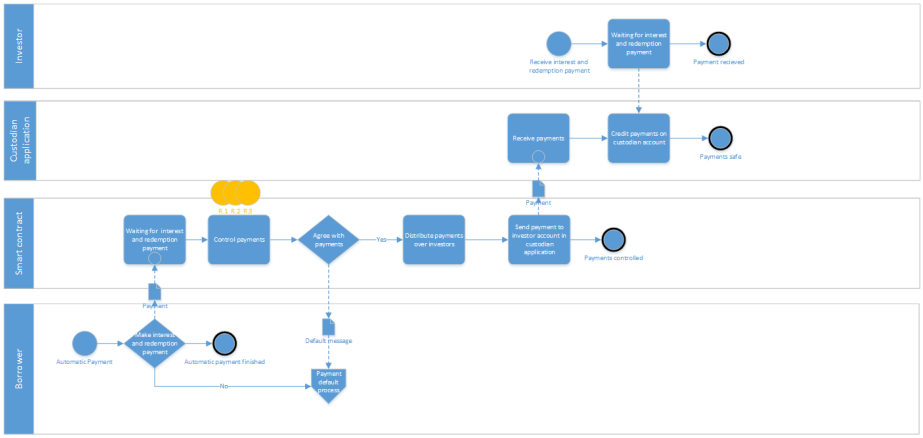


Figure 19: Payments

5.5.5 Secutoken mortgage default

In this process, the smart contract has taken over the task of the SPV in the model 'mortgage default' in the current system. The SPV normally does calculations to decrease the securities in value when defaults occur. Now, in the blockchain model, the smart contract conducts these valuations by preprogrammed conditions (SPV), and the investors can see on were the devaluation has occurred in the mortgage pool by the transparency of the blockchain (TRANS).

The process begins at the smart contract. When the contract does not receive the payments on time or not at all, then the smart contract sends a notification of a possible default to the originator, and the originator has to take care of the customer service. The originator attempts to find a payment solution with the borrower. If such a solution arises, then the tokens are re-valuated, but there is still a chance that the payments will recover; for example, when somebody loses a job and finds another one a couple of months later. In this situation, arrears can be paid back, but if there is no payment solution found, then the originator has to sell collateral through an auction. With the funds from the collateral auction, the residual dept is paid off, and the remaining money compensates the investors through the smart contract (VA,VB CASH). This compensation is equal to the periodical payments made over the entire period. Figure 18 displays this BPMN model. Next, the secutokens are revalued and decreased in value. Controls of data are done by the originator and automatically by the smart contract when default occurs and residual payments are made.

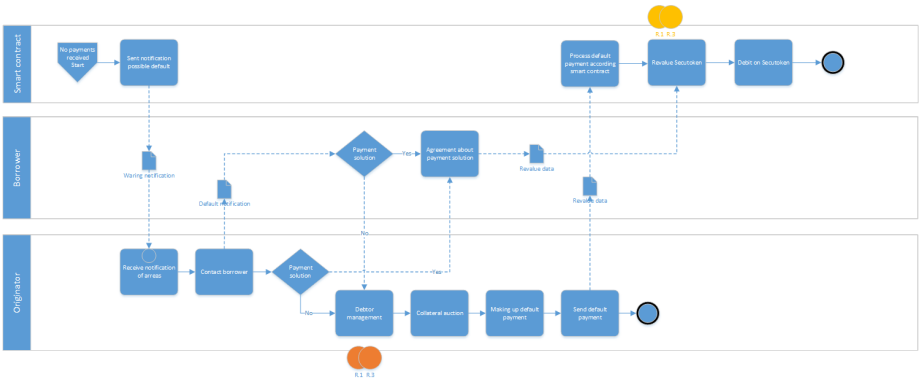


Figure 20: Secutoken mortgage default

5.5.6 Valuation of secutoken

While developing the model to manage mortgage funding through securitisation based on blockchain, an important question was raised several times:

How can the secutokens that are generated out of the mortgage pool be valuated?

This question was asked by several interviewees. When the topic was discussed, the notion of the valuation of the bond was brought up every time (D,F,BOND). The secutoken could be valued in the same way as such a bond. In this example, the secutoken's collateral is one linear mortgage, and the token's yield is the interest and redemption. A linear mortgage is taken for simplicity it is possible to use other kinds of mortgages but this will complicate the calculation what is not necessary to describe the principle.

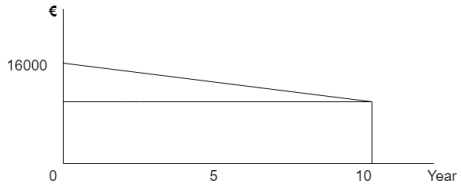


Figure 21: Linear mortgage

In Figure 21 , a linear mortgage of 100,000 euros is shown with a maturity time (t) of 10 years. The redemption payments (r) are 10,000 euros per month and stay the same over the 10 years total. The interest (I) rate is 6% per year, but because of the redemption payments, the interest value decreases linearly (linear mortgage). This linear mortgage is mathematically displayed in Figure 21.

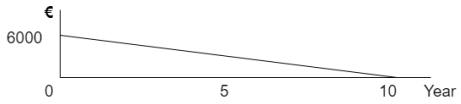


Figure 22: Interest

In Figures 22 and 23, the interest and redemption payments are displayed in two different figures. The interest starts at 6,000 euros a year and decreases with a directional coefficient of $a = -300$ along the line $i = -300t + 3000$. These interest payments go straight to the investors minus any transaction costs.

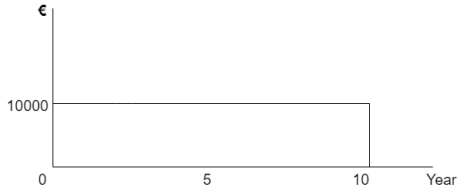


Figure 23: Redemption

In Figure 23, the redemption payments are shown. These redemption payments remain the same over 10 years and are deducted from the token value every time they are paid off. In the value spreadsheet in Appendix G these calculation are displayed with the aforementioned mortgage. The 10-year linear mortgage has a mortgage value of 100,000 euros. This mortgage is split up in 10 secutokens with a value of 10,000 euros in year one in the beginning. Every year, the redemption and interest is paid over the outstanding amount. The value of the secutoken decreases by 1,000 euros each year through the redemption, it is also a possibility that the redemption payments are stored in the smart contract, and are paid out at majority. This could be the face value of the secutoken. The interest is the pure earnings for the investor. However, account must be taken of the market interest rate says expert D, this has a influences

on the price of a bond now the secutoken, with the following formula (Shapiro 2008,p.463):

$$\frac{1+oldmarketinterest}{1+newmarketinterest} * (Pold - Redemption) = Pnew$$

In the value spreadsheet, this formula is applied in year three to four, which is when the market rate decreases in percentage. This also means that the bond has a relatively higher yield than the market rate does, so the value of the bond rises. If the market rate rises, the bond loses value. This trend also happens with the secutokens in the system, see the spreadsheet.

Unfortunately, there are more factors that impact the valuation of the secutoken, such as defaults and risk profiles. However, the valuation of the token is not the focus of this research; this example merely demonstrates how to potentially valuate a secutoken in this system. In this valuation, 10 secutokens are valuated on the basis of one linear mortgage. In reality, the RMBSs are valued on the basis of a mortgage pool with different kind of mortgages and multiple risk profiles, which also could be implemented in the valuation of the secutoken but this requires lots of knowledge in econometrics. A full explanation of this potentiality is therefore beyond the bounds of this research.

6 Business process model validation

The focus group is divided into four expert discussions that have been used to answer the fourth subsidiary question and to validate the new business process model. Two validation discussions (VA, VB) were conducted with previous interviewees; these interviewees validated the business process models of the current situation and the new model. The two other expert discussions were held with new experts who are both involved in a blockchain securitisation project. The partner (VC) has gained a great deal of knowledge on securitisation in his career and is now involved in several blockchain projects. The new senior associate (VD) is more involved in the projects because his knowledge of blockchain, and he currently even runs his own radio station, 'Satoshi Radio'. This radio station creates a weekly new podcast about the ins and outs of blockchain and related subjects.

The discussions were held on the basis of the created models of the researcher. These models are demonstrated in the discussion and were thoroughly checked with the experts. The recommendations given by the expert have been taken into consideration and recognised by the researcher when implemented in the models. The most striking results are discussed below.

6.1 Discussion VA

The first validation of this discussion is about the payments in the model "overview process and scope." The payments that the borrower makes are on a monthly basis, and the payments from the originator to the SPV are also monthly. However, the payments from the SPV to the investor are quarterly (VA.CASH).

Three processes in the overview were discussed: bringing securities to the market (A), cashflow management (B), and default management (C). These are the processes were liquidity, transaction costs and speed fall short. Because process A is almost one time in a securitisation transaction and is only used one time by setting up a transaction. VA thinks blockchain could better used in B and C because these are processes that are used continuously throughout the lifetime of the transaction (VA.HAND).

In the discussion of "buying a RMBS over the counter" in D.1,The researcher discovered that the stakeholder "broker" can be preformed by different parties. Sometimes this intermediary is an independent broker platform, but sometimes it is an investment bank. This depends again on how the securities are sold. Sometimes securities out of one transaction are sold in different ways. For example, class A securities out of the purple storm transaction are sold by the Euroclear, while the other ones are sold by Deutsche Bank (Intertrust 2016). These are two different intermediaries with the same purpose: couple the selling party with the investor. Euroclear is an international trade platform (broker) that also manages the settlements (clearing house) for institutional investors; these products are then traded by their own platform (exchange). The Deutsche Bank usually trades the securities over the counter, were the buyer and seller are brought together without an exchange. However, VA stated that there is always an intermediary between the buyer and the seller (VA.STAKE).

Before this discussion, the custodian had an active role in the trade of the securities. But VA said that the custodian only is used to store the securities and keep them safe. This is improved in the model (VA.CUSTO). The selling party in the model was first the SPV. But now it is the RMBS Seller. It is possible that the SPV sells the securities, but only at the beginning of the transaction, and thereafter they can be traded between investors. The RMBS seller is only the SPV at the start of the transaction (VA.SPV). Another improvement on the model made on the basis of a recommendation of VA is that the investor is not able to cancel his bid when he confirms the offer of the intermediary. Therefore, the only party that can neglect the offer is the RMBS seller. If they confirm, the bid is completely settled. In the model before, the investor could still change his mind. This is not possible anymore (VA.TRADESEC).

On the basis of the interview with interview A (Intertrust), the model "RMBS payments" was constructed. Firstly, the researcher discussed with VA the exact task of the paying agent. He said that it is an intermediary that does not do much. The SPV manages the interest and redemption calculation over the RMBS payments and the paying agent asks for this information on behalf of the investors. This intermediary is between the SPV and the clearing systems is provided in the model. This controlling step of the paying agent is determined by law according to VA. This is because the SPV cannot pay the clearing systems directly. VA was amazed at the number of intermediate steps that must be taken until the payments are received by the investor. However, VA affirmed that this model seems to be correct (VA.STAKE).

Additionally, the controls in the RMBS payments model were discussed. It was important to control input, processing, and outputs of transactions in terms of correctness, completeness, and timeliness to reduce the risk of defaulting on payments for the investor. According to VA, it was impossible to implement all the controls in the models because these controls are implemented in IT application and executed by employees of the stakeholders. This thesis is focused on process optimization and not on control measures. VA stated that every stakeholder in this process has an ISAE report of 55 pages, to implement all these controls is not necessary if this is not the focus of the research. However, VA emphasised that it is important to name because controls are really important in this kind of financial processes (VA.CONSEC).

Lastly, the researcher displayed the valuation model of the tokens. He discussed with VA linking the tokens to the collateral of the loan or linking the tokens directly to the loan. VA concluded that the tokens should be linked to the loan because the loans are the products that are issued. This is the same principle as linking loans to bonds (VA.BOND).

6.2 Discussion VB

First, the proposed simplified version of the blockchain business process is given and explained to the expert. (This model can be found in the summary.) After the explanation, he confirms that this system will indeed cut out many stakeholders from the current process: 'If a smart contract is able to do this (distribute payments and keep track of tokens in the accounts of investors), it will indeed cut a lot of stakeholders out of the current process'.

When discussing the cash flows in the simplified model in Figure 1 VB discovered an error in the model: the cash flow to buy the tokens went from investor to the token marketplace to the smart contract specialist. However, this was incorrect . The correct model of the cash flow is as follows: A one-time payment by the investor goes to the token market where the secutokens are traded. The originator, which also has an account in the token market, receives the money from the investor through the token market. This money ends up in the custodian application of the token market or is immediately transferred to originators own account. This improvement is made to the model after the discussion.

The problem of storing a fiat currency in a smart contract was brought up again. This is still a major problem for this system, because smart contracts only work with their corresponding payment method. If Ethereum smart contracts are used, ether cryptocurrency must be used for payments. This is still unimaginable, as ether is not a globally accepted payment method (VB.MONPAY).

Controls also arose in this discussion. VB recommended checking for controls when there is a transfer of data. When there is a data transfer, this data should be controlled for accuracy. To implement all the controls of this system will be an impossible job, it will be based on a whole study, VB said (VB.CONSEC).

The loan tape in the RMBS payment model is also discussed. Loan tapes are only used by the SPV, because this is source data. Loan tapes are not used by the originator or the paying agent. The loan tape is the calculation of the payments the originator has to transfer to the SPV every month. The paying agent does not uses a loan tape but rather calculates the payments based on the data provided by the investors. This is corrected in the model (VB.CASH).

VB also discussed commingling risk, which involves blending funds at a bank. As an example, a bank with mortgages every month receives the redemption and interest payments. But these payments end up in one account, so it is unclear which money is from which mortgage. This is only a risk of the bank, VB says, and not of the SPV or paying agent because these are special entities set up for this task, and they do not have problems from different inflows of cash, thus commingling risk (VB.COMING). Many interviewees mentioned that when a mortgage is no longer being paid, is be removed from the pool and replaced to reduce losses. But VB does not agree with this model (VB.MMP), saying,

'When a mortgage is not paid anymore, it goes to the debtor management of the originator. The originator wants to reduce losses and will sell the collateral as soon as possible. When the SPV does not get interest or redemption payments anymore, the mortgage receivable remains on the balance sheet. Then, this is debited to the least creditworthy notes'

Also, when a mortgage reaches its time of maturity in the pool, new mortgages are sometimes bought in. However, this does not occur often, most of the Dutch securitisation transactions have expire dates. If there is a value change in a mortgage pool such as a default mortgage, the RMBS bond normally decrease in value, VB explained (VB.MMP).

6.3 Discussion VC

VC discussed valuating tokens like a bond and giving tokens different risk profiles for risk diversification in investor portfolios. The tokens must also have cash flows for the interest and redemption payments. VC liked the plan but wanted to know what kind of information would be on the token. Because loan to value is an important risk measure that investors want to know before buying the tokens, VC seemed to think it was important to link the secutoken to the original mortgage. This way, the investor had the most important information about an investment (VC.BOND). Credit agencies base their models on this data to assess the risk profiles of RMBSs. If this data was available to investors, they could check their investments themselves and would make the credit agency redundant (VC.CRAG)

In the discussion, the identity of the nodes in the network was discussed. VC said that banks were not too enthusiastic about a public blockchain where everyone could participate, in terms of security and energy consumption. He did see the advantage of more nodes providing more reliability, but malicious nodes must be kept out out of the system and permission should be given only to parties involved (VC.PRIPUB). The transparency given to involved parties will also facilitate supervision, which decreases the work in controlling the system repeatedly, according to VC (VC.TRANS).

The custodian and the auditor stakeholders were discussed also. Custodians must focus more on IT security, says VC, because this is an important aspect to trading with digital assets (VC.CUSTO). The accountant's way of working will also change. If protocols are written for smart contracts, many controls executed now by accountants will be carried out by these contracts. The auditor will no longer be doing the verification but rather verifying whether the smart contracts are doing what they should be doing (VC.AUDIT) and whether consensus mechanisms are working as expected. In other words, 'the job of the accountant is to do the job, but now becomes to check if the work is done well by the smart contracts', according to VC.

The incentives for banks to securitise mortgages were also discussed. VC agrees that Basel IV is pushing up capital requirements for banks. When capital requirements increase, the equity of the bank also increases. This equity is considerably more expensive then when this equity is lent out. This is because shareholders request a certain amount of equity as dividends; on the other hand, this does not happen when the money is lent out, when it generates income. Also, Dutch people tend to save relatively less money than the rest of the world. Dutch people save more money in their pension funds; as a result, the pension funds have a surplus of stagnant money. This money is by law 'safer' than traditional savings because it is less liquid (savings can be withdrawn at anytime, whereas pensions can be drawn from beginning at age of 67). Thus, pensions need to have fewer reserves. This is also true for insurance companies, which only have to pay when there is a distinct occurrence (VC.LAWSEC)

In the future , the bank's only function will be customer service, not funding once capital reserves increase. According to VC, the ideal situation is that when the bank originates a mortgage, the mortgage can be directly securitised into tokens. This way, the loan skips the bank's balance sheet. Then, the bank is fully responsible for the customer service and origination of the mortgage, and the pension and insurance companies are responsible for the funding

(VC.PRESECBL).

The tokens that are created in this model will indeed increase liquidity, said VC, and this will reduce the liquidity risk in the system. VC mentioned that he was talking about insurance companies and pension funds as the investors, but if mortgages could be sold in smaller parts using tokens, a completely new market for small investors will emerge. This could increase funds for the mortgage market and makes funding mortgages cheaper (VC.LIQ).

6.4 Discussion VD

VD took part in a sprint project researching how to put mortgages on the blockchain. When he saw the simplified model, he argued that it was necessary to put the mortgage on the blockchain first, before selling them as secutokens to investors. But the challenge is to link something that is not digital (a mortgage) to a smart contract. For this reason, a bank or notary will always be needed. To make things more difficult, smart contracts can be executed only when certain conditions are met, and mortgage contracts are dependent on the decisions of notary, lawyers, and banks. These actors must, then, be the oracles of the smart contracts (VD.SMART).

VD does not see the value of blockchain in this process. He does, however, agree that blockchain can be used to create an environment where different companies run on one database. Thus, mortgage information could be saved on one network, on which different companies could execute tasks in the process of origination of mortgages. For example, when notaries and lawyers plug into the network, they could verify different requirements of a mortgage contract, so the mortgage could be originated. No copies or paperwork would need to be sent to all of the different stakeholders in the process (VD.BENFBL).

VD also agrees that smart contracts could trace the volume of tokens of each investor. They could also distribute interest and redemption payments. But this is also difficult, because these payments could never be paid in fiat currency (VD.MONPAY).

VD asked, 'Are we now thinking about a solution for a problem or are we creating a problem by the solution?' The smart contracts on the blockchain can do only pay out in their corresponding currency. So, an Ethereum smart contract could only make payouts in the cryptocurrency ether. But when ether does not have a stable value, this is not done by banks (VD.SMART).

VD also noted that automated contracts already exist, so is it really necessary to implement smart contracts on the blockchain? He gives the example of a phone plan as an automatic contract; it is already automated so that once a customer reaches the limits of the plan, they are no longer able to call. This kind of function has long been automated. The only difference of a smart contract on the blockchain is that is saved in a decentralised network (VD.SMART).

VB was interested in the security tokens. Ownership can be put on a token, and tokens are easily tradable on the blockchain. In this trading system, third parties are no longer necessary. The most interesting aspect would be the part beginning from the mortgage pool and how they can be traded over the blockchain. The bank than has a pool of mortgages already rated by the rating agencies (as in the current system) However, the bank now does not issue debt papers for securities, but rather tokens that have the same characteristics as securities (VD.TOKO).

VD agreed that securitisation is currently a time-consuming and expensive process (VD.TIME,COST). If this market is made more liquid, a new market could emerge for small investors (VD.LIQ). However, there are too many risks to put this process on a public blockchain, and if it runs on one bank's private blockchain, VD asked, what is the purpose? A central database would work in the same way, he argued (VD.PRIPUB). Perhaps the solution is to create a permissioned blockchain for all of the involved parties (NHG, pension funds, insurance companies, and small investors), and all these parties are controlled by an anti-money laundering or 'know your customer' protocol. These parties would then control the system and could buy the tokens. Then, the token has to represent a share of a bond, and the value of the token is then that it is easy to trade.

The current problem is that investors do not have transparency in the products they buy, and this is why these products need to be rated by rating agency. Blockchain brings a good alternative to providing transparency for these products, so that investors can get the information of the underlying product directly. They can see what the products consist of and if they really meet requirements in terms of LTV, geographical location, or NHG (VB.CRAG).

6.5 Summery Validation

Four discussions were held with experts in the field of blockchain and securitisation. Table 6 summarises each of the expert discussions. The general interview was encapsulated into a short sentence with the code that refers to the codebook. The codebook is used to discover patterns by counting the number of times a subject is discussed in an interview to increase internal validity. This data can be found in Appendix I. It only counts when the interviewee enters the discussion to emphasise the importance of the topic. The repetitions in the interviews and discussions are then summed because the expert discussions also had an influence on the design of the blockchain-based business model. In Figure 24, a graph is used to display the repetitions. In the figure, it is evident that LAWSEC is the most repeated subject in the interviews by its number of counts. The interviewees consider this to be most important and that this should be primarily considered when designing the model. The figure also ranks the importance by the number of repetitions of the interviewees so that this importance can easily be included in the design.

The five most frequently repeated subjects are from subjects MMP, LAWSEC, LIQ, CASH, and CONBL. These subjects are remarkably repeated more often than others. MMP concerns managing the mortgage pool. This discussion was held with interviewees C, D, F, and VB. C and D had the opinion that mortgages were removed from the mortgage pool when the default. F and VB were of the opinion that these losses were credited to the investor, because they had more knowledge and experience with securitization, so this trade-off was made in the model.

The LAWSEC subject reveals the importance of the laws are that are involved in securitisation. In almost all the interviews, a discussion was held on the laws concerning blockchain and securitisation. Therefore, these laws thoroughly discussed in the thesis.

Twenty LIQ is the number from the subject liquidity issues on the RMBS securities that can be solved by trading secutokens over the blockchain.

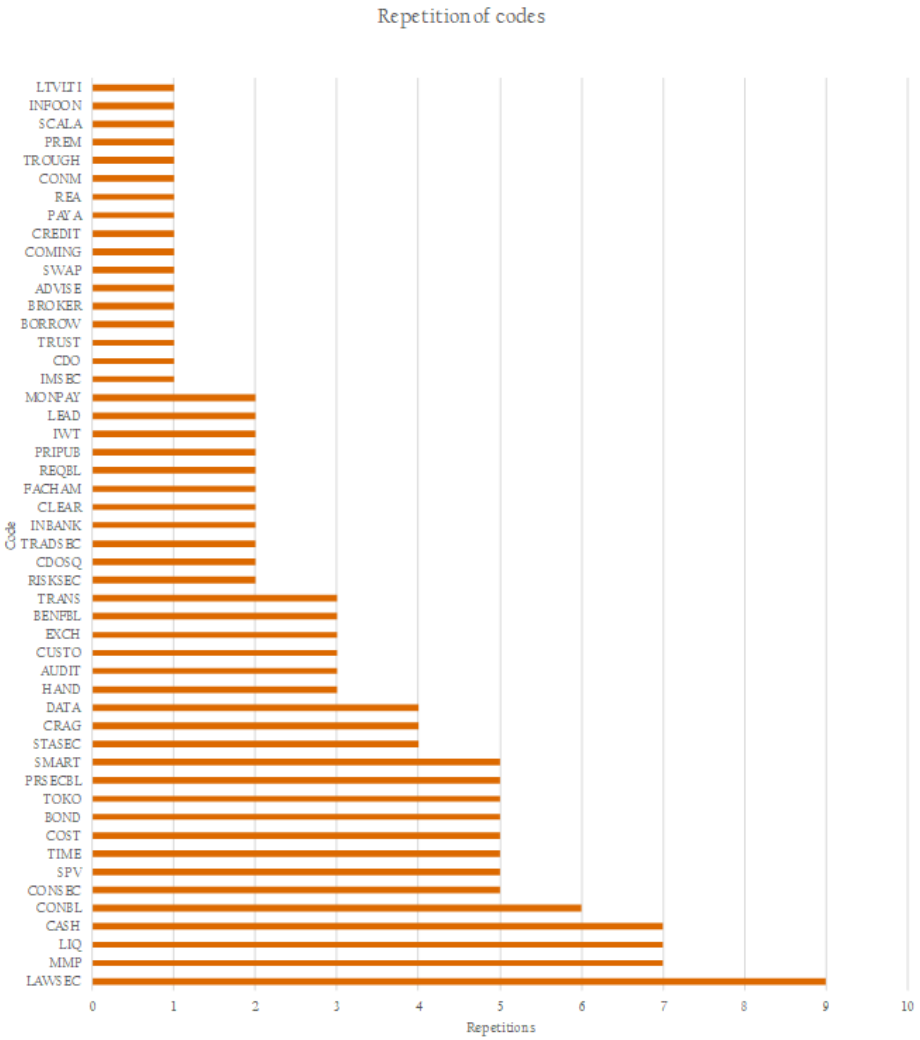


Figure 24: Repetition graph

CASH was another repeated subject of the interest and redemption payment process. This process was therefore thoroughly researched and included in the model design. Based on blockchain, this process can be created more efficiently in terms of costs and transaction times.

The last subject to discuss is the control framework (CONBL) for a decentralised blockchain-based securitisation process. This subject received much attention because of the importance attached to it by the interviewees. Unfortunately, this kind of blockchain control framework is not fully developed yet and still in the developing phase at PwC. In the BPMN model and root cause analysis a small amount of attention is given to these controls, but further controls broadens the scope of the research too much. This subject is ultimately suitable for further research.

Summery validation discussions	
#	RQ4
VA	- Borrower payments monthly, originator to SPV monthly, from SPV to investor quaterly (CASH) - Process A,B,C good for blockchain implementation because of many manually processes (HAND) - Validation of stakholder in buy process (STAKE) - Validation of stakholder in buy process (STAKE) - Custodian will become important (CUSTO) - The securities must be able to trade between investors (TRADE) - Validation stakeholders en functions in payment process (STAKE) - Validation of controls, correctness, timeliness and completeness. There are to much controls to implement in a thesis, this is not the focus (CONSEC) - Loans must be linked on loans like bonds not on the collateral (BOND)
VB	- Validation of simplified model - Storing fiat currency in smart contract is impossible, could be a problem (MONPAY) - To much controls for a thesis, don't focus to much on this (CONSEC) - Commingling risk only at the bank (COMING) - Default are not taken out the mortgage pool, this is credited to the investor (MMP) - Sometimes mortgage are purchached by the SPV when loans end their majority (MMP)
VC	- Tokens linking to bonds, good idea (BOND) - Credit rating agency's become redundant (CRAG) - No public blockchain for banks, security and energy consumption (PRIPUB) - Blockchain could make supervision more easy (TRANS) - Smart contract will take over tasks of auditor (AUDIT) - This market needs more liquidity, this also can impact the price of mortgages (LIQ)
VD	- To link somethin not digital to a smart contract is very dificult, a mortgage is always depemdent from not digital factors as a decision of notary or banks. (SMART) - If blockchain is implemented it must create a network from all stakeholders as nodes, so they can plug in the network and collaborate (BENFBL) - Smart contract can track tokens, but payments are difficult because fiat can not be stored (SMART) - Security tokens will be interesting for this system (TOKO) - Time, Cost, and liquidity is problem of securitisation (COST, TIME, LIQ) - Credit agencies will lost their function, investors can judge their investments themself (CRAG)

Table 6: Summery validation discussions

7 Conclusion and discussion

The last chapter of this thesis includes the conclusion and the discussion of the results. In the conclusion, the subsidiary questions of the research are extensively addressed to provide a final answer to the primary research question of the thesis. In the discussion, the limitations of the research are assessed and recommendations for future research on this topic are explored.

7.1 Conclusions

In the introduction to the thesis, the research objective was outlined:

To help financial service institutions identify and analyse the potential opportunities of blockchain technologies in the business process of securitising mortgages.

This objective could be achieved by answering the following four subsidiary questions and finally answering the primary research question of the thesis:

Subsidiary questions:

1. What is the current status of the business process securitising mortgages and what opportunities could blockchain bring within the status quo?
2. What are financial service institutions' requirements for a new RMBS business process based on blockchain technology?
3. What would a new blockchain-based securitisation business process model look like?
4. Do experts agree that the business process model created in this research is a viable option?

Primary question:

How can the business process of securitising mortgages be redesigned and is a public blockchain the appropriate technology when implemented in the ICT architecture?

In the next section, the subsidiary questions are answered, followed by the primary research question. Thereafter, there is a discussion of the limitations and recommendations.

7.1.1 Subsidiary question 1

What is the current status of the business process securitising mortgages and what opportunities could blockchain bring within the status quo?

Currently, mortgage originators are under a significant amount of pressure by regulators, shareholders, and supervisors to increase economic performance. By adhering to the new Basel IV accord, Dutch mortgage originators must hold more reserves for their mortgage portfolios . These extra reserves increase the equity on the balance sheet, which increases the cost of capital at the expense of economic performance. Supervisors also pressure originators by their increasing focus on viability and economic sustainability. This drives the demand for transparency in vulnerabilities of bank and its exposure to company- and market-related risks. Through these external factors, transferring illiquid assets off the balance sheet in a more transparent way is becoming a solution for the increased equity requirements. Unfortunately, securitisation transactions are complex, costly, and time consuming because of the involved stakeholders. Therefore, without structural improvements to transferring illiquid assets of f the balance sheet, the impact on mortgage originators' ability to sustain the current economic performance will be significant in the future.

With the introduction of blockchain, the private centralised institution (bank) can be replaced by a distributed network accessible to everyone. This distributed network aggregates the forces of the participants (nodes) and performs the activities now fulfilled by expensive intermediaries. It is also possible to execute more complex programs on the blockchain, also known as smart contracts. These contracts will disrupt the financial sector and lead to automated value and asset transactions, thereby reducing costs and transactions times. These benefits are relevant to the securitisation business process, in which many transactions and manual activities between different stakeholders drive up cost and transaction times. Furthermore, blockchain is also able to relieve supervisors' demands for transparency. The distributed network is able to function as a public database in which every node (stakeholder) in the network possesses all the data.

The current process of securitising mortgages is not only expensive, time consuming and non-transparent, but the products they bring to the market are also significantly illiquid. This illiquidity is caused by the size (large packages) and the manner in which these securities are sold. Therefore, many investors are excluded from the RMBS market, which is a missed opportunity for originators. Furthermore, this liquidity problem also causes liquidity risks for the institutional investors. These packages cannot easily be traded to prevent or minimise losses when markets are turbulent. Tokenising by smart contracts or splitting these large packages may create a more liquid market and give small investors more exposure to the mortgage market. This could reduce the liquidity risk of the securities and open a new market that can increase demand of these products. By selling off loans, one can more easily avoid banks' capital requirement premiums. This effect can work through to the beginning of the value chain and can certainly benefit the borrower with a lower interest rates on his mortgage.

7.1.2 Subsidiary question 2

What are financial service institutions' requirements for a new RMBS business process based on blockchain technology?

As discussed in the first subsidiary question, the increased capital requirements of the Basel 4 accord is one of the main reasons to increase the cash

position by securitising mortgages. It is not an option to refuse this extensive regulation: the balance sheets have to load off to prevent the high costs of capital. However, these capital requirements do not apply to the insurance sector that is regulated by Solvency II. In this law, the link between risk and reserves still applies and no standardised output floor is introduced as well. This regulatory arbitrage makes it lucrative to fund mortgages with 'cheaper' money from insurance companies. This means that mortgage originators have to transfer their credit risk to the insurance industry. The pension industry is lucrative as well; this industry also has stagnated money and less strict capital requirements. Furthermore, adhering to the terms of the regulation of GDPR and MiFID II are also important requirements for the implementation of a new blockchain-based business process. Following GDPR a blockchain-based business process should work without any personal and sensitive information. The European Union has raised transparency constraints with MiFID II and the Dutch regulators AFM and DNB also wants to have more transparency i the books of mortgage originators. Vulnerabilities and banks' exposure to company and market risk are indicators if they generate acceptable short and long term returns to sustain stability in the financial industry.

Two of the most important technical requirements for an international network are that every system of every stakeholder can interface with each other and that the system is reliable. This already causes many problems, even now with the various types of software and hardware. The innovative power of blockchain is restrained by the current information technology systems which provide the data for the blockchain. A reliable process is important for all the stakeholders: borrower, bank, and investor. Research by PwC has determined that 0.4 percent of all mortgage loans are securitised off balance, which totals 2.8 billion euros. Although this is a small piece of the whole mortgage market of 500 billion in the Netherlands, the expectation of the experts is that this will increase rapidly with the new regulations (PwC 2018b). When blockchain is implemented, the business process must be able to manage a large amount of society's assets. Therefore, it is vital that the new business process is comprehensively tested on its robustness and reliability.

Lastly, in the securitisation process, not only banks have to innovate, but also the parties that collaborate in a securitisation transaction. The various stakeholders all have their own investment in the process; some parties know that they will become redundant when this technology begins to disrupt the industry. If this occurs, they will protect that stake and lose the ambition to innovate. Implementing blockchain in the industry requires the whole industry transform, not only one party. This delays the innovation process, especially in an industry with relatively conservative structures, such as large Dutch banks.

7.1.3 Subsidiary question 3

What would a new blockchain-based securitisation business process model look like?

Before designing the blockchain-based securitisation business process model, a comprehensive stakeholder analysis was conducted. This analysis determined that there were many stakeholders involved in the current business process, and that this number of stakeholders was enormously reduced by implementing

blockchain. However, following the advice of the experts, there are also a few stakeholders who become more important when this blockchain-based business process is implemented. The most drastic change in the new business model is the removal of the SPV. Implementing a SPV by transferring the assets is the major expense in terms of legal and administrative costs. Smart contracts take care of the SPV in the blockchain-based securitisation business process model. The mortgage portfolio is now accommodated and programmed in a smart contract. This smart contract is able to create secutokens (security tokens) with information on the mortgage portfolio (Kim 2018). These secutokens can be sold peer-to-peer through the blockchain on an OTC basis between investors or through a token exchange that matches buyers and sellers. The blockchain then manages the recording, clearing, and settlement of transactions, which makes the clearing houses and previous systems redundant. This will decrease transaction fees and increase the time to market by removing manual processes.

In this business process, it is assumed that secutokens have the same legal status as RMBS bonds. When buying a secutoken on the token exchange, the investor buys a small part of the mortgage portfolio and also obtains the corresponding risk. In order to take this risk, the investor receives the monthly payments earned by interest and redemption payments. Because the smart contract is able to trace which investors are in possession of the tokens, the smart contract can distribute the redemption payments to the personal accounts of the investors. This functionality of the smart contract is able to replace stakeholders such as the SPV trustee and the paying agent. These parties' main purpose is to calculate and distribute the periodic payments. Therefore, the paying agent performs a controlling function over the SPV trustee. This control function is no longer necessary with a smart contract where the information is always visible on the blockchain. The payment guarantee therefore shifts to the originator who is responsible of the smart contract application. Because these smart contracts are not compliant by itself and still need to be validated for compliance, the auditor remains indispensable.

A smart contract specialist is included in the model, because there are no parties suitable for this activity that have been found yet. The role of the smart contract specialist is to program these contracts in a way they are able to convert the mortgage portfolio into valuable secutokens. Because of the lack of knowledge on blockchain and smart contract application, the bank has to put more investment into research and development to initiate specialised teams within the bank. When they ignore this development, a smart contract fintech company will take over this activity in the future, which would be a missed opportunity for the bank.

When a secutoken is sold, the credit risk is transferred to an investor, and the mortgage originator can remove the illiquid loan assets from his balance sheet, in return for liquid cash. This ensures that they have to keep fewer capital reserves based on the Basel IV accord. The received cash earned by selling the tokens can be used to originate more mortgages and sustain the economic performance of the bank. This process is illustrated in the simplified model in Appendix E

The important characteristics of blockchain are discussed in the literature review in section 1. Two decision trees are depicted in Figures 12 and 13; the first determines if the business process is suitable for blockchain in general and the second details which kind of blockchain is needed for the business process.

Now that the results of the interviews are known, it is clear that blockchain suits the business process because the throughput will not be as large as with ordinary transactions. This is because the system needs shared write access for all the important stakeholders and it cannot be assume that all the stakeholders can trust each other. A public ledger will not be an option because from the interviews is concluded that a certain level of control is needed by the network of authorised parties. On the question of which kind of blockchain is needed, this question is determined by the permissioned blockchain to the Ethereum blockchain. The level of control will be maintained and smart contracts with a token approach will support the functions of the business process.

7.1.4 Subsidiary question 4

Do experts agree that the business process model created in this research is a viable option?

The current BPMN process models are validated individually by experts. The blockchain-based BPMN models are not validated individually, but the overall idea is discussed. The results of the validation discussions are elaborated to create viable models. Firstly, the current model of securitisation was evaluated in the discussion VA and VB and several improvements were made. In the overview model in Figure 15, the expert and the researcher concluded that there were three business processes in which blockchain could be applied to the securitisation process. The processes are indicated with the letters A (buying RMBS process), B (RMBS payments process), and C (mortgage default process). Following the experts' advice, A and B were continuous processes, and thus most efficiency could be obtained from these processes. For the "buying a RMBS" model, it was discovered that RMBS are sold in two different ways: OTC and exchange trades. Both trading processes use expensive intermediaries that can be removed by implementing blockchain. The expensive transaction fees these intermediaries employ and the liquidity problem of the RMBS products exclude small investors. When the product liquidity increases and transaction fees decrease, small investors could become a part in the investors slice. This could improve market prises of mortgage products and decrease the liquidity risk for large institutional investors. The experts concluded that the BPMN model "RMBS payments" does not need improvements, and therefore this business process was ultimately suitable for implementing blockchain. In the "default management" model indicated by the letter C in Figure 15, many interviewees discussed customising a mortgage portfolio in between the transaction period in the current system. The experts clarified that this is only done exceptionally when loans mature, but not when loans default. When a loan defaults, losses that occur are charged to the investor by devaluing the securities. Adjustments were made to the first BPMN model because of these remarks.

The discussions with experts confirmed that the three current business models consider all steps that belong to the core of a securitisation transaction. This process was never modelled before in BPMN and can now be improved by blockchain technology.

The blockchain-based models were evaluated by VC and VB on the basis of the simplified model displayed in Figure **??**. VC directly remarked on the function of the credit rating agency. This stakeholder was still in the model to

evaluate the secutokens before they are brought to market. The expert was positive that the credit rating agency should disappear with the transparency of the financial products in the blockchain. This is only the case when the blockchain is transparent to the investors and investors are able to check the RMBS on the level of the individual mortgages that their tokens consist of. This remark provided the adjustment of removing the credit rating agency that approves safe investments in this model. Furthermore, activities from exchange and custodian were discussed and their importance was confirmed, if they are able to change their activities to operate with blockchain. This applies to all stakeholders that are not eliminated from the current process, and the stakeholders must prepare themselves for the blockchain transformation.

In addition to the critical views of the experts to validate and adjust the models, the study also considered the research components of constructive, internal, and external validity. The constructive validity of the data was increased through the use of an interview protocol and discussions based on the literature, which aimed to find the correct operational measures for the target concepts. This was the proper way to build the model, but nevertheless the interviews could have been even more structured, because afterwards a large amount of superfluous information was discovered. Internal validity was increased by creating a codebook and comparing outcomes of the interviews and discussions with each other. In Figure 24, it is easy to identify the subjects that play a large role in the results of this thesis. Important aspects of this figure were also included in the model design. The external validity was guaranteed by the way interviewees were selected. This was mainly conducted by matching companies, departments, and interests to the subject in question. This created a meaningful discussion on blockchain and securitisation.

7.1.5 Primary research question

How can the business process of securitising mortgages be redesigned and is a public blockchain the appropriate technology when implemented in the ICT architecture?

Implementing blockchain technology in business processes remains difficult. However, this research has found a technique for identifying, discovering, structuring, and analysing the securitisation business process so that it can be redesigned to adopt blockchain. First, data was gathered from literature and interviews to prepare the redesign process. To structure this data, two analyses were executed: a *stakeholder analysis* to discover and ultimately reduce the large number of stakeholders involved, and a *root cause* to identify the individual root causes of the problems by implementing the blockchain based model. With all this collected information, BPMN models were designed in two phases. In the first phase, BPMN models were designed from the current model to provide the researcher with knowledge of the securitisation process. With the knowledge of the stakeholders, external factors, and the current process, the researcher designed a new blockchain-based business process in BPMN. The entire design process in this thesis is structured by the information systems (IS) research framework of Hevner et al. to ensure the relevance and effectiveness of the information system research (Hevner et al. 2004). Using the information system research framework is a proper method to design a blockchain-based business

model because it enables the researcher to gain crucial knowledge and structures the design phase of the model. During the research process, it was noticed that the 'governance' and 'stakeholders' elements also contributed to the design of the blockchain-based business process. It was observed that LAWSEC is the most repeated subject in the interviews (see Figure 24), and in the interviews there are always different stakeholders discussed. In the IS research framework of Hevner there is less regard to these elements. But today, the 'network' element has become more important in information systems with blockchain. This must be added to the Hevner research framework to conduct proper research on these new network information systems.

By considering requirements and stakeholders, this research proved that this design process can create a viable blockchain-based securitisation business process model in BPMN approved by expert discussions. The BPMN model is of importance to clarify this blockchain-based business process to the less technical managers and policy makers and help these decision makers understand the complex concepts behind the technical process, and thus hopefully accelerate the innovation of blockchain-based securitisation. Because this research can be used to create a bridge between the non-technical and technical decision makers, the next steps should be taken to create a working prototype with further technical knowledge.

In terms of the last part of the research question concerning whether a public, permissionless blockchain is a proper technology for implementation in the securitisation business process, not all experts were excited. Often discussions arose on the topic of private, permissioned, and consortium blockchains, because experimentation often occurs on this type of network at banks and consultancy firms. These firms use these networks to reduce computational power (energy) and maintain a certain level of privacy and control. However, these networks actually refer to a decentralised database with authorised parties. This subtracts from the distributed idea of blockchain in which everyone is able to participate and carries out their own checks so that no central party is necessary. However, a transparent, public, and permissioned network, such as a network of authorised nodes that are used by all stakeholders with a convenient consensus mechanism to control the validation of decisions, is able to reduce costs, transaction times, liquidity risks, and difficulties with regulatory compliance. In such a network, the network is able to bring parties together and find solutions to current problems in a collaborative manner with blockchain. However, this requires the attitude of the entire financial ecosystem to evolve.

7.2 Discussion

7.2.1 Limitations of research

This research has an exploitative character and the business process model was constructed based on qualitative research. The model therefore gives the reader an indication of the best possible design based on this data set. The scope of the research was too broad to include the entire securitisation process of mortgages, but by the reaching regulations, the process of selling off the mortgages to the investor became most important. The mortgage origination process itself, swap parties in the securitisation process and future predicting controls discussed with interviewee E are left out. While designing the model, it was noticed that

blockchain is a relatively young technology; this can be observed in risk and control frameworks which are not fully developed for the technology. Controls to prevent various problems in the model are discussed where the information is sufficient. Legal incentives to use blockchain in the field of securitisation are also discussed, but legal aspects of the implementation are still immature and therefore were purposefully omitted.

After almost 10 years, blockchain is still in its emerging phase. However, Bitcoin increased interest in blockchain technology and generated articles and academic papers. It is sometimes difficult to determine the real truth between contradictory articles and papers written by people with a poor understanding of the technology. This becomes a limitation of conducting research on blockchain because it is hard to find reliable information that the research can be based on. Therefore, it is of great importance that the researcher remains objective in terms of all the information and data collected.

The interview data set was limited in diversity because of the high number of PwC interviewees. In the last six months at PwC, the researcher attempted to speak with clients about their activities in the field of blockchain and securitisation. However, the clients had enough knowledge of both concepts. Clients are still in the orientation phase of the blockchain transformation. One third of the interviews were conducted with people outside PwC. This limitation could have influenced the external validity and reliability of the research.

While interviewing experts, it was noticed that experts provided different answers to the questions. This can be caused by knowledge gaps on the subjects they were asked about. Securitisation experts that relayed that they have little knowledge of blockchain gave relatively simple answers to blockchain questions, and the reverse was also the case. The experts with proper knowledge of both concepts were most informative to this research. This was determined by reaching conclusions and answers that were directly opposed to the literature review and thus researcher's prior knowledge did not influence the results.

Using blockchain to improve the business model of securitisation requires knowledge of blockchain and securitisation. The researcher was not specialised in both of these concepts and therefore had to conduct research on these during the literature review. This lack of in-depth knowledge of structural finance and IT systems is a limitation of the research. The BMPM models and valuations of financial products are simplified and are based on a business perspective. The model in this thesis demonstrates what the future possibilities of blockchain are in a securitisation business process.

7.2.2 Recommendations

The literature on blockchain indicated that there is a great amount of friction in terms of privacy, legal, and contractual arrangements on data recording. In the interviews, only the new privacy law GDPR was discussed, but there are also many trusted parties active in the 'trust market': accountants, notaries, and organisations that manage central registers such as the Chamber of Commerce (KvK) and the Kadaster. Blockchain technology will have a significant impact on their activities, because it is able to automate recording processes now granted to these parties and organizations. If blockchain technology has real longevity, it will have a serious impact on laws and regulations for smart contract enforcement and parties on the trust market. It is therefore neces-

sary to keep these laws and regulations in mind before developing these kinds of business processes, because it is difficult to make changes to the underlying technology when a blockchain-based system is developed. To avoid these mistakes, additional research is suggested on a compliant blockchain-based law and regulation framework.

In addition to a legal and regulatory framework, a control framework is also necessary to manage all the risks involved in a blockchain-based securitisation process. The big four auditors are working on this kind of framework, but these are not yet finished. After such a framework is finished, the controls have to be integrated. Controls are roughly described in this thesis, but only the controls discussed with the experts were built into the models. The controls of data transfer were discussed and built into the BPMN models, but further controls are not included because of the complexity and time restrictions. Further research is therefore required. However, general blockchain-based controls are discussed in the root cause analysis in chapter 5. This can be a first step to delineating the first steps of a control framework.

To build a more complete model of the transformation of the securitisation process, it is recommended that future researchers conduct more interviews with other involved stakeholders and with the stakeholders that are eliminated by the blockchain-based process, such as the clearing houses. Furthermore, interviews must be conducted with IT specialists with an understanding of the special programming languages to program blockchain application and smart contracts such as Solidity and Hyperledger to discover if the technology can fulfill the purposes of this thesis. Unfortunately, these programmers are difficult to find, especially in the Netherlands. If the possibilities are secure, then it is definitely technologically feasible. A focus group of securitisation specialists, blockchain programmers, regulators, and econometristians should be organised to build a definitive prototype. A control framework must be created for this prototype to reduce the various risks corresponding to the model and must be extensively tested on reliability when it is completed. For example, this can be done under the guidance of the Financial Conduct Authority in the UK. This financial authority allows businesses to test innovative products, services, business processes, and delivery mechanisms on a small scale in the real market in the regulatory sandbox.

Trust is also a commonly discussed topic. Blockchain may redefine trust in the global economy (Underwood 2016), but one should also consider the fraud cases in the cryptocurrency world and the failing blockchain systems. This statement cannot be realised before the technology is fully developed and robust enough to replace the trusted centralised parties that are running the current monetary system.

A BPMN model with all events that occur by trading secutokens, or a 'petri net model', could be also made. In the petri model, events can be taken over from the BPMN model. However, research must be conducted on the conditions in which events are executed. A petri net model also functions with tokens and could be able to visualise the route the tokens follow through the various stakeholders and can map the conditions they must meet to travel to the next event.

It is important that these products do not resemble the products that were sold before the financial crisis. The lack of quality review of the underlying mortgages caused enormous risks for investors, partly due to credible credit

agencies who labeled unsafe products as viable. It is important that the investor has access to all the product information on source of the investment. As a result, it is recommended that research be conducted on transparent investment products which contain all the information that investors require. It was proposed in one of the interviews that a Hypotoken (Hypotheek token) be created on the blockchain that contains information like LTV, NHG, and geographical information of the mortgage, and these tokens would be pooled in a smart contract with secutokens. The secutoken should be able to refer to the information on the Hypotoken from which they were created. To complete the entire cycle of securitization, research on the origination of mortgages with a Hypotoken is advisable.

Blockchain itself also suffers from two problems in terms of this business process. The first is the possibility of storing and paying out fiat currency with smart contracts. These important activities of the business process are only possible in platforms with corresponding currency. An Ethereum smart contract can only store and perform payouts in the cryptocurrency ether. Using fiat currency is not possible, and will never be possible in the environment of Ethereum or the other blockchain platforms that exist at the moment. Furthermore, when Ether does not have a stable value and not accepted globally, it is difficult for financial institutions to implement. A solution could be a quick swap application that can swap cryptocurrencies for fiat money.

It would also be worthwhile to research if these improvements can be achieved without blockchain. Automation of the administrative processes of record organisations can improve costs and transaction times. The liquidity issue can also possibly be solved without blockchain. It is recommended to research the possibilities of bringing the large packages with RMBS in smaller pieces to the market. This could be performed in the same manner that financial institutions create CFD's. However, regulation will play a major role in this process; this would also be a fruitful topic of research. For example, it should be determined whether it is legally possible to bring small value products derived from mortgage portfolio to the market. This market will attract an international market with small investors, which also raises questions on international jurisdiction.

Finally, in this thesis, a model has been created to innovate the business process to securitise mortgages. This new innovative business process can also serve as basis for the securitisation of other loans such as: small to large business loans, car loans, credit card loans, and student loans.

References

Alderotti, Fabio and Vedant Thakur (2016). *Presale: PURPLE STORM 2016 B.V.*

Angelides, Phil et al. (2011). "The financial crisis inquiry report: final report of the National Commission on the Causes of the Financial and Economic Crisis in the United States". In: *Revised Corrected Copy February* 25.

Aru, Iyke (2018). *Blockchain: Shifting From Internet of Information to Internet of Value*. URL: https://cointelegraph.com/news/blockchain-shifting-from-internet-of-information-to-internet-of-value.

Baron, Jon (2017). "Blockchain, accounting and audit: What accountants need to know". In: *Accounting Today*.

Brito, Jerry and Andrea Castillo (2013). "BITCOIN A Primer for Policymakers". In:

Buterin, Vitalik et al. (2013). "Ethereum white paper". In: *GitHub repository*.

Buterin, Vitalik (2017). *The Meaning of Decentralization – Vitalik Buterin – Medium*. URL: https://medium.com/@VitalikButerin/the-meaning-of-decentralization-a0c92b76a274.

Castor, Amy (2017). *A (Short) Guide to Blockchain Consensus Protocols*. URL: https://www.coindesk.com/short-guide-blockchain-consensus-protocols/.

Chinosi, Michele and Alberto Trombetta (2012). "BPMN: An introduction to the standard". In: *Computer Standards & Interfaces* 34.1, pp. 124–134.

Christidis, Konstantinos and Michael Devetsikiotis (2016). "Blockchains and smart contracts for the internet of things". In: *Ieee Access* 4, pp. 2292–2303.

CMS (2018). *How to Use the Fishbone Tool for Root Cause Analysis*. URL: www.cms.gov/Medicare/Provider-Enrollment-and-Certification/QAPI/downloads/FishboneRevised.pdf.

Coffey, Amanda and Paul Atkinson (1996). *Making sense of qualitative data: complementary research strategies*. Sage Publications, Inc.

Cooper, Harris M. (1998). *Synthesizing research : a guide for literature reviews*. Sage Publications, p. 201. ISBN: 0761913475.

Coval, Joshua, Jakub Jurek, and Erik Stafford (2009). "The economics of structured finance". In: *Journal of Economic Perspectives* 23.1, pp. 3–25.

Davidson, Paul (2008). "Securitization, liquidity, and market failure". In: *Challenge* 51.3, pp. 43–56.

DeCuir-Gunby, Jessica T, Patricia L Marshall, and Allison W McCulloch (2011). "Developing and using a codebook for the analysis of interview data: An example from a professional development research project". In: *Field methods* 23.2, pp. 136–155.

Demiroglu, Cem and Christopher James (2012). "How important is having skin in the game? originator-sponsor affiliation and losses on mortgage-backed securities". In: *The Review of Financial Studies* 25.11, pp. 3217–3258.

DNB (2016). "DNBulletin: Bancaire hypotheekportefeuilles onder de loep". In:

— (2018). *Statistisch Nieuwsbericht: Securitisaties naar laagste niveau sinds financiële crisis*. URL: https://www.dnb.nl/nieuws/nieuwsoverzicht-en-archief/Statistischnieuws2018/dnb373697.jsp.

Drucker, Vanessa (2017). *Securitisation: European recovery lags the US*. URL: https://www.ipe.com/reports/special-reports/credit/securitisation-european-recovery-lags-the-us/10019265.article.

Dudovskiy, John (2013). *Exploratory Research - Research Methodology*. (Visited on 03/05/2018).

DutchBlockchainCoalition (2017). "Smart contracts als specifieke toepassing van de blockchaintechnologie". In: pp. 0–66.

Dziembowski, Stefan et al. (2015). "Proofs of space". In: *Annual Cryptology Conference*. Springer, pp. 585–605.

Gabison, Garry (2016). "Policy considerations for the blockchain technology public and private applications". In: *SMU Sci. & Tech. L. Rev.* 19, p. 327.

Hellwig, Timothy and David Samuels (2008). "Electoral accountability and the variety of democratic regimes". In: *British Journal of Political Science* 38.1, pp. 65–90.

Hevner, Alan R et al. (2004). "DESIGN SCIENCE IN INFORMATION SYSTEMS RESEARCH 1". In: *Design Science in IS Research MIS Quarterly* 28.1, pp. 75–105.

Hycner, Richard H (1985). "Some guidelines for the phenomenological analysis of interview data". In: *Human studies* 8.3, pp. 279–303.

Iansiti, Marco, Karim R Lakhani, and Hassan Mohamed (2017). "The truth about blockchain - It will take years to transform". In:

Intertrust (2016). *Prospectus Purple storm*.

Johnson, R Burke (1997). "Examining the validity structure of qualitative research". In: *Education* 118.2, p. 282.

Khatwani, Sudhir (2018). *What Is The Bitcoin Mempool & Why It Matters??* URL: https://coinsutra.com/bitcoin-mempool/.

Kim, D.H. (2018). *Compliance for Security Token Issuance and Trading*.

Kitzinger, J (1995). "Qualitative research. Introducing focus groups." In: *BMJ (Clinical research ed.)* 311.7000, pp. 299–302. ISSN: 0959-8138.

Koch, Stefan et al. (2017). *Bringing Basel IV into focus*. URL: https://www.mckinsey.com/business-functions/risk/our-insights/bringing-basel-iv-into-focus.

Kroot, Jan and Evangelos Giouvris (2016). "Dutch mortgages: Impact of the crisis on probability of default". In: *Finance Research Letters* 18, pp. 205–217.

Lamport, Leslie, Robert Shostak, and Marshall Pease (1982). "The Byzantine generals problem". In: *ACM Transactions on Programming Languages and Systems (TOPLAS)* 4.3, pp. 382–401.

Lemke, Thomas P, Gerald T Lins, and Marie E Picard (2014). *Mortgage-Backed Securities*. Thomson Reuters Westlaw.

Lotz, Ulrich and Philipp von Websky (2017). *Applying Blockchain in Securitization — Deloitte US*. (Visited on 05/02/2018).

Malinova, Katya and Andreas Park (2017). "Market Design with Blockchain Technology". In:

Mehrez, Gil and Daniel Kaufmann (2000). "Transparency, liberalization, and financial crisis". In:

Mendling, Jan et al. (2018). "Blockchains for Business Process Management -Challenges and Opportunities". In:

Miles, Matthew B et al. (1994). *Qualitative data analysis: An expanded sourcebook*. sage, pp. 43–44.

Mori, Taketoshi (2016). "Financial technology: blockchain and securities settlement". In: *Journal of Securities Operations & Custody* 8.3, pp. 208–227.
Mulligan, CJ et al. (2018). "Blockchain Beyond the Hype". In: *World Economic Forum. http://www3. weforum. org/docs/48423_Whether_Blockchain_WP. pdf. Accessed*. Vol. 2.
Nakamoto, Satoshi (2008). "Bitcoin: A peer-to-peer electronic cash system". In:
— (2009). "Bitcoin: A Peer-to-Peer Electronic Cash System". In:
Neuron (2018). *List of cryptocurrency exchange hacks*. URL: `https://rados.io/list-of-documented-exchange-hacks/`.
Pagano, Marco and Paolo Volpin (2012). "Securitization, transparency, and liquidity". In: *The Review of Financial Studies* 25.8, pp. 2417–2453.
Perkins, Mark (2017). *Why Blockchain is Internet 2.0 – Marc Perkins – Medium*. (Visited on 05/01/2018).
Pesch, Udo (2015). "Engineers and active responsibility". In: *Science and engineering ethics* 21.4, pp. 925–939.
Polymath (2018). *Polymath - White Paper*. (Visited on 04/26/2018).
Popov, Serguei (2018). "The Tangle". In:
Popper, Nathaniel (2016). *A Venture Fund With Plenty of Virtual Capital, but No Capitalist - The New York Times*. (Visited on 05/01/2018).
PWC (2017). *Basel IV: Big bang or the endgame of basel III*.
— (2018). *Glossary and Comparison of Blockchain and DLT Platforms*.
PwC (2017). "IFRS 9, Financial Instruments,Understanding the basics". In: *Accounting Studies*, p. 41.
— (2018a). *Control Framework*.
— (2018b). "Proposal: From securitisation to Tokenisation". In:
Raskin, Max and David Yermack (2016). *Digital currencies, decentralized ledgers, and the future of central banking*. Tech. rep. National Bureau of Economic Research.
Reilly, Frank K and Keith C Brown (2011). *Investment analysis and portfolio management*. Cengage Learning.
Reis-Roy, Calvin (1998). *Rating Securitisation Structures*. URL: `https://papers.ssrn.com/sol3/papers.cfm?abstract%7B%5C_%7Did=2189523`.
Research Methodology (2018). *interviews - Research-Methodology*. (Visited on 03/14/2018).
Rikken, Olivier (2018). *Blockchain & Smart Contracts, A brief intro and their possible effect on the financial systems and industry*.
Sandelowski, Margarete (1998). "The call to experts in qualitative research". In: *Research in nursing & health* 21.5, pp. 467–471.
Sectors, Fixed Income (2005). "Asset-Backed Securities-A primer on asset-backed securities". In: *Dwight Asset Management Company*.
Sekaran, Uma and Roger Bougie (2016). *Research methods for business: A skill building approach*. John Wiley & Sons.
Shapiro, Alan C (2008). *Multinational financial management*. John Wiley & Sons.
Shields, Patricia M and Nandhini Rangarajan (2013). *A playbook for research methods: Integrating conceptual frameworks and project management*. New Forums Press.
Simkovic, Michael (2013). "Competition and crisis in mortgage securitization". In: *Ind. LJ* 88, p. 213.

Statica (2018). *RMBS issuance in the U.S. 2002-2017 — Statistic*. URL: https://www.statista.com/statistics/275746/rmbs-issuance-in-the-united-states/.

Tapscott, Don and Alex Tapscott (2016). *Blockchain revolution: how the technology behind bitcoin is changing money, business, and the world*. Penguin.

Tavakoli, Janet (2005). "CDOs: Caveat Emptor,"". In: *GARP Risk Review* 26.

Thompson, Collin (2016). *The difference between a Private, Public & Consortium Blockchain*. URL: https://www.blockchaindailynews.com/The-difference-between-a-Private-Public-Consortium-Blockchain_a24681.html.

Underwood, Sarah (2016). "Blockchain beyond bitcoin". In: *Communications of the ACM* 59.11, pp. 15–17.

Varvasovszky, Zsuzsa and Ruair Brugha (2000). "A stakeholder analysis". In: *Health policy and planning* 15.3, pp. 338–345.

White, Stephen A. (2016). *Introduction to BPMN*.

Yin, Robert K (2009). "Case study research: Design and methods (applied social research methods)". In: *London and Singapore: Sage*.

Zhang, Erik and Da Hongfei (2018). *NEO White Paper*. URL: http://docs.neo.org/en-us/whitepaper.html.

Appendix

A Research diagram

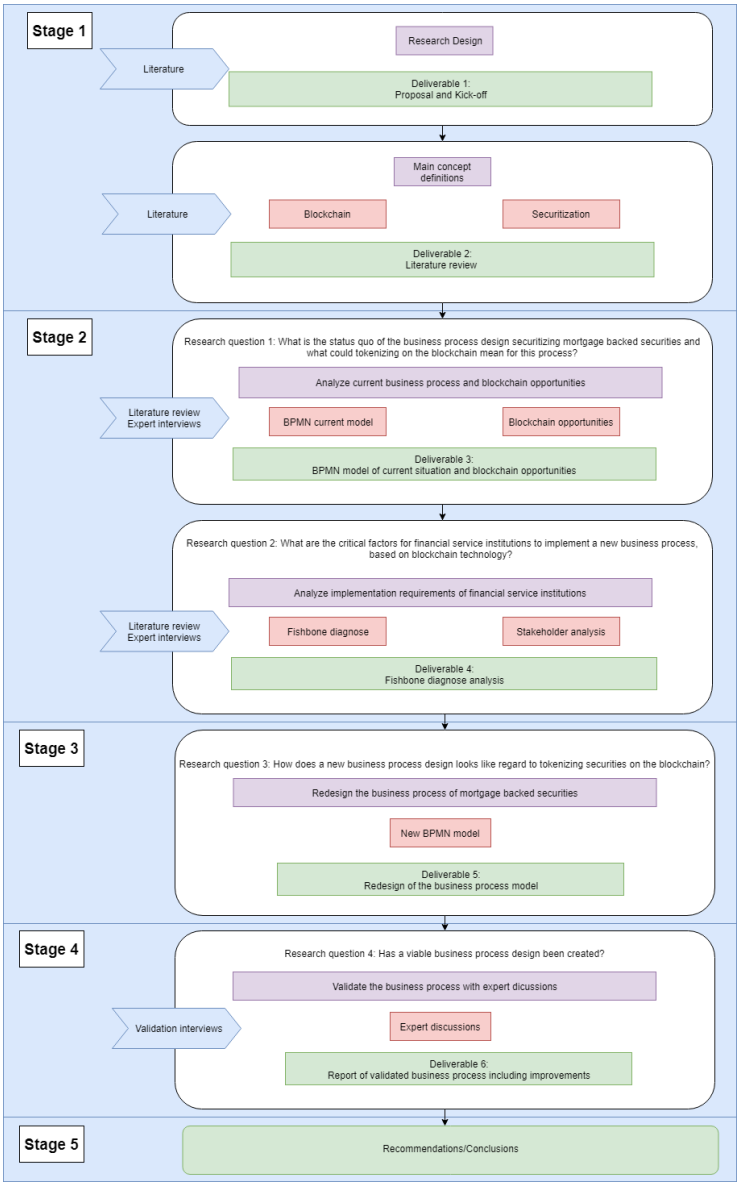


Figure 25: Research diagram

B Stakeholder analysis tables

B.1 Stakeholders in the current securitisation process

Stakeholders analysis					
Stakeholder	Responsibility	Interests	Influence	Impact	Attitude
Borrower	The lender by the originator to fund his mortgage	High, needs a mortgage for buying real estate	Low	Low	Neutral
Investor	Take risk to earn a certain amount of return by buying financial products	Get return on their investment and care about the safety of their investment instrument	High	Low	Positive
Originator	Provide mortgages to borrowers	High, Need to write mortgages from balance sheet to meet capital requirements and need to collect money to continue issuing mortgages	High	High	Neutral
Arranger	Bring parties together to set up a securitisation transaction	The arranger gets a fee to set up an transaction and bring parties together	Low	High	Negative
SPV	Owns the mortgages	Get payed by involved parties to maintain the mortgage pool	Low	High	Neutral
Security trustee	Ensures that the repayments and the interest received by the originator are correctly distributed among the various investors	Get's a fee from the investors to protect their rights	Low	High	Negative
Credit rating agency	Give credit ratings to financial products	Get payed by collaborating parties to rate the financial products	Medium	High	Negative
Broker	Brings the securities to the market	Get transaction fees	Low	Medium	Neutral

Paying agent	Distribute the principal and the interest payments among the investors before the payments are made to the clearing systems	They get administration and transfer fees	Low	High	Negative
Clearing systems	Systems that take care of the distribution of payments to the custodian applications from the investors	Raise fees from transactions	Low	High	Negative
Custodian application	Keeping securities safe	Is payed on yearly basis by investor and raising fees of transactions	High	Medium	Neutral
Servicer	Ensure that repayments and interest are paid on time. In practice, this is usually the originator itself but is sometimes outsourced, because it owns data to record those transactions	Get fees from collaborating parties	Low	High	Negative
Swap counter party	A swap counter-party will takeover risk exposure in return of premiums, based on the likelihood that the contract defaults	Get paid for interest risk	Low	High	Negative
Regulators	Provide laws to ensure a robust financial system	A stable financial system	High	Low	Neutral
Supervisors	Control if financial institutions following the law	Get fees for legal advise	High	Low	Neutral
Auditors	Auditors carry out controls to secure the process	Get fees for compliance and financial controls	Medium	High	Positive

Table 7: Stakeholders in current securitisation process

B.2 Stakeholders in the blockchain-based securitisation process

Stakeholders analysis		
Stakeholder	Responsibility	Interests
Borrower	The lender by the originator to fund his mortgage	High, needs a mortgage for buying real estate
Investor	Take risk to earn a certain amount of return by buying financial products	Get return on their investment and care about the safety of their investment instrument
Originator	Provide mortgages to borrowers	High pressure to offload balance sheet to meet capital requirements
Platform provider	Takes care of the blockchain platform such as Ethereum	Get fees for using the platform
Smart contract specialist	Generate smart contracts for every transaction	Get's a fee to set up and maintain the smart contract
Token exchange	Brings the secutokens to the investors	Get transaction fees
Custodian application	Safe storage for tokens	Get payed by investor through transactions
Swap counter party	A swap counter-party will takeover risk exposure in return of premiums, based on the likelihood that the contract defaults	Get paid for interest risk
Regulators	Provide laws to ensure a robust financial system	A stable financial system
Supervisors	Control if financial institutions following the law	Get fees for legal advise
Auditors	Auditors carry out controls to secure the process	Get fees for compliance and financial controls

Table 8: Stakeholders in blockchain based securitisation process

C Root cause diagrams

C.1 Root cause current securitisation process

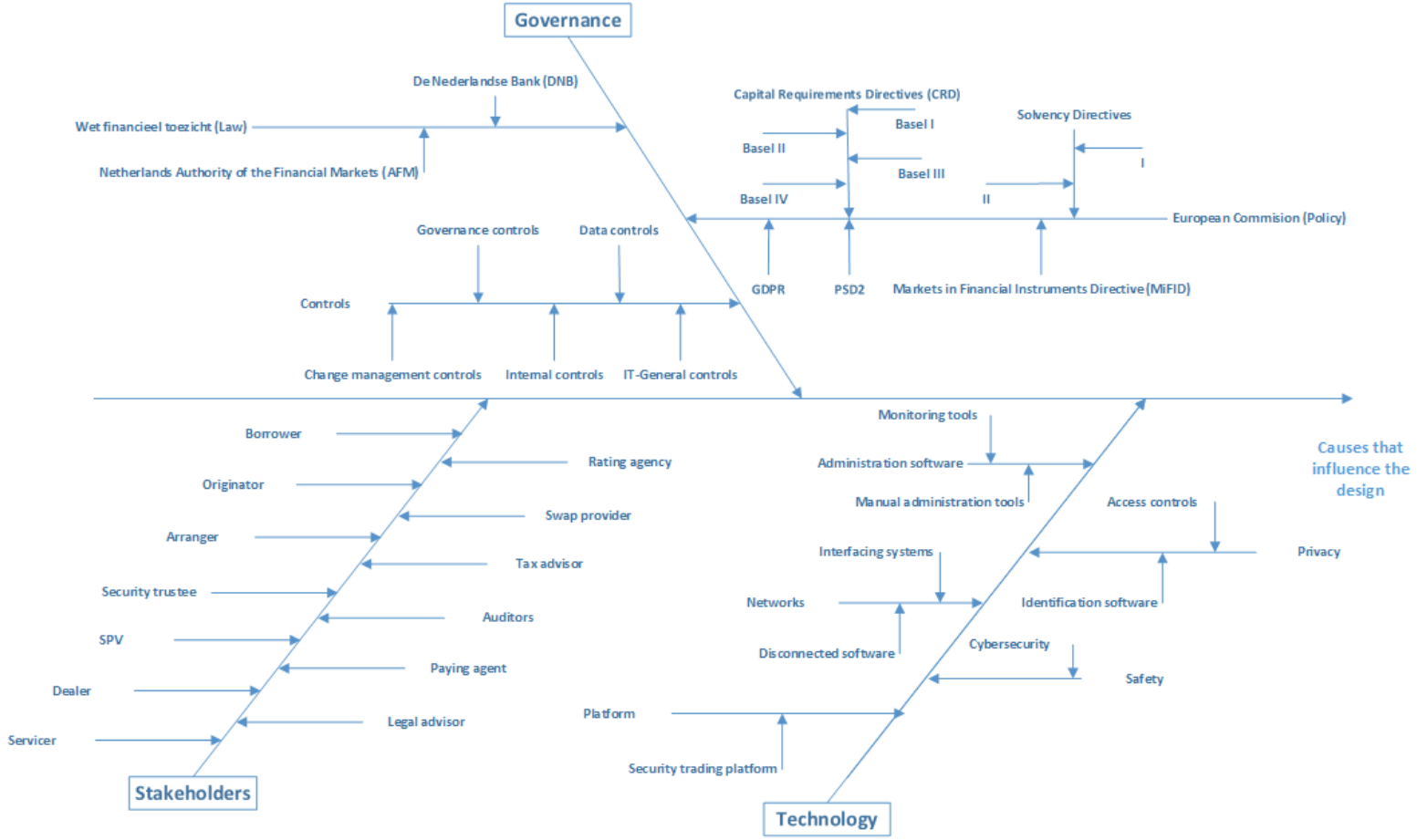


Figure 26: Fishbone securitisation

C.2 Root cause blockchain-based securitisation process

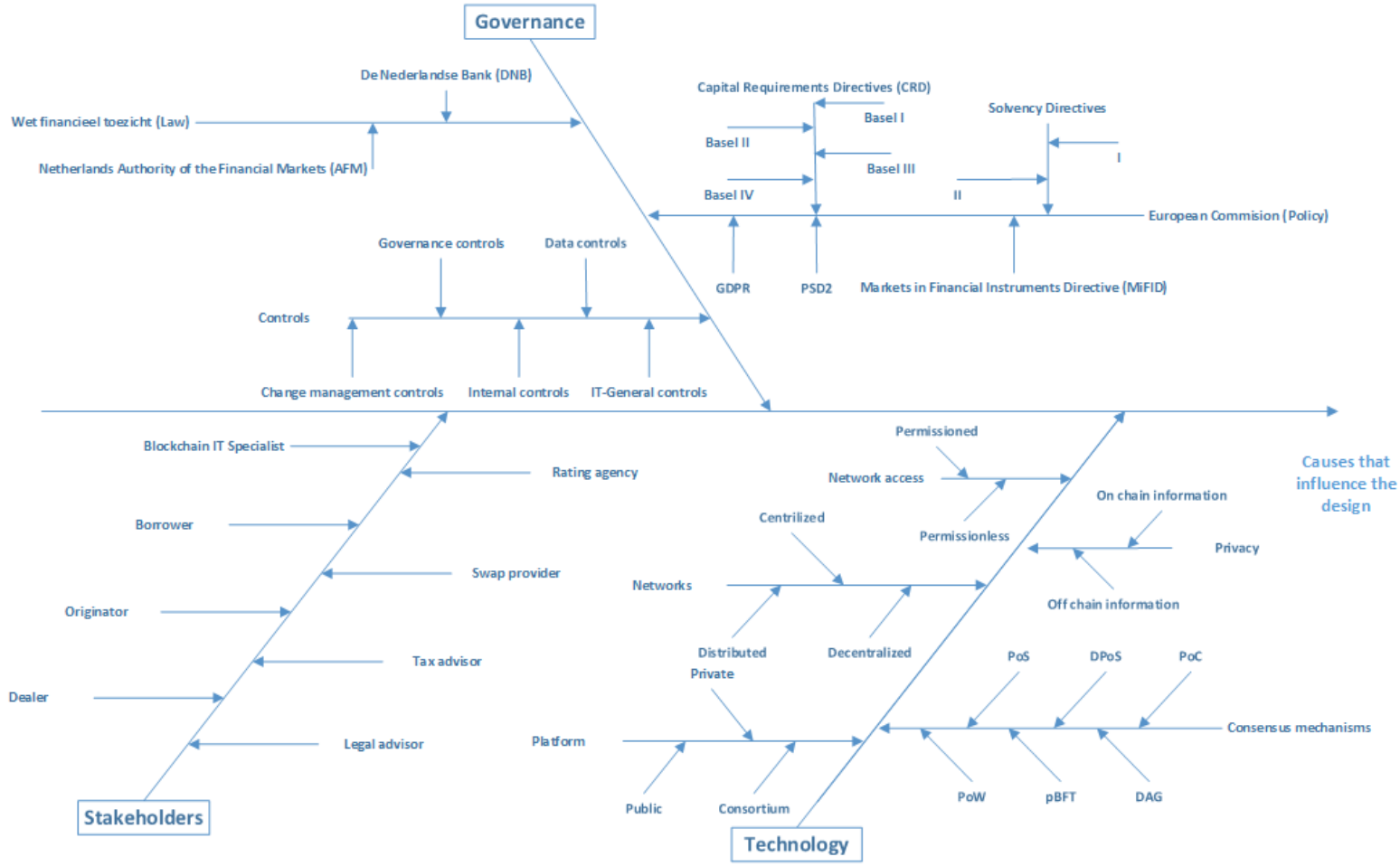


Figure 27: Fishbone blockchain-based securitisation

D BPMN models

D.1 R-MBS buy process

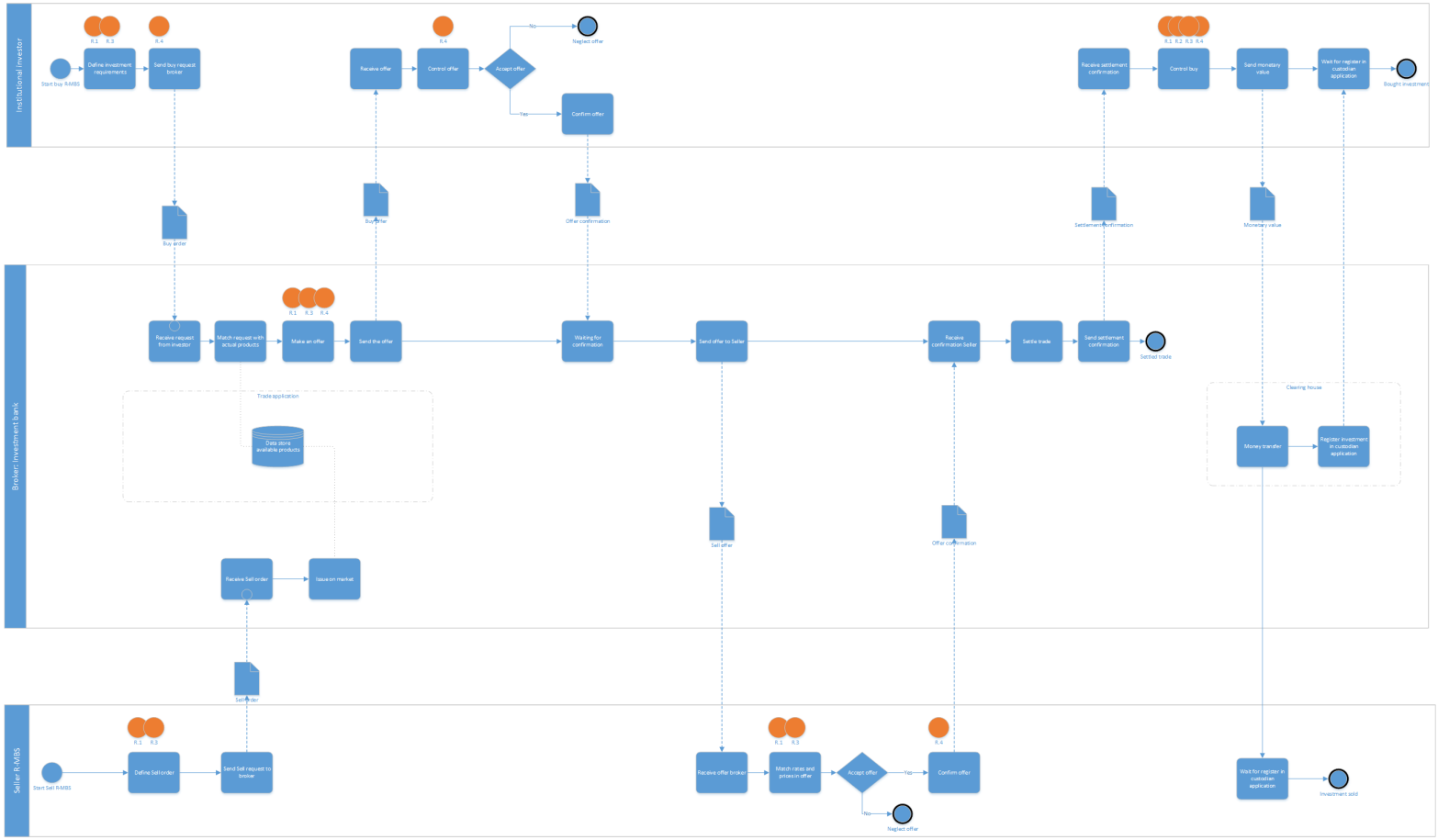


Figure 28: Buy R-MBS

D.2 R-MBS payment process

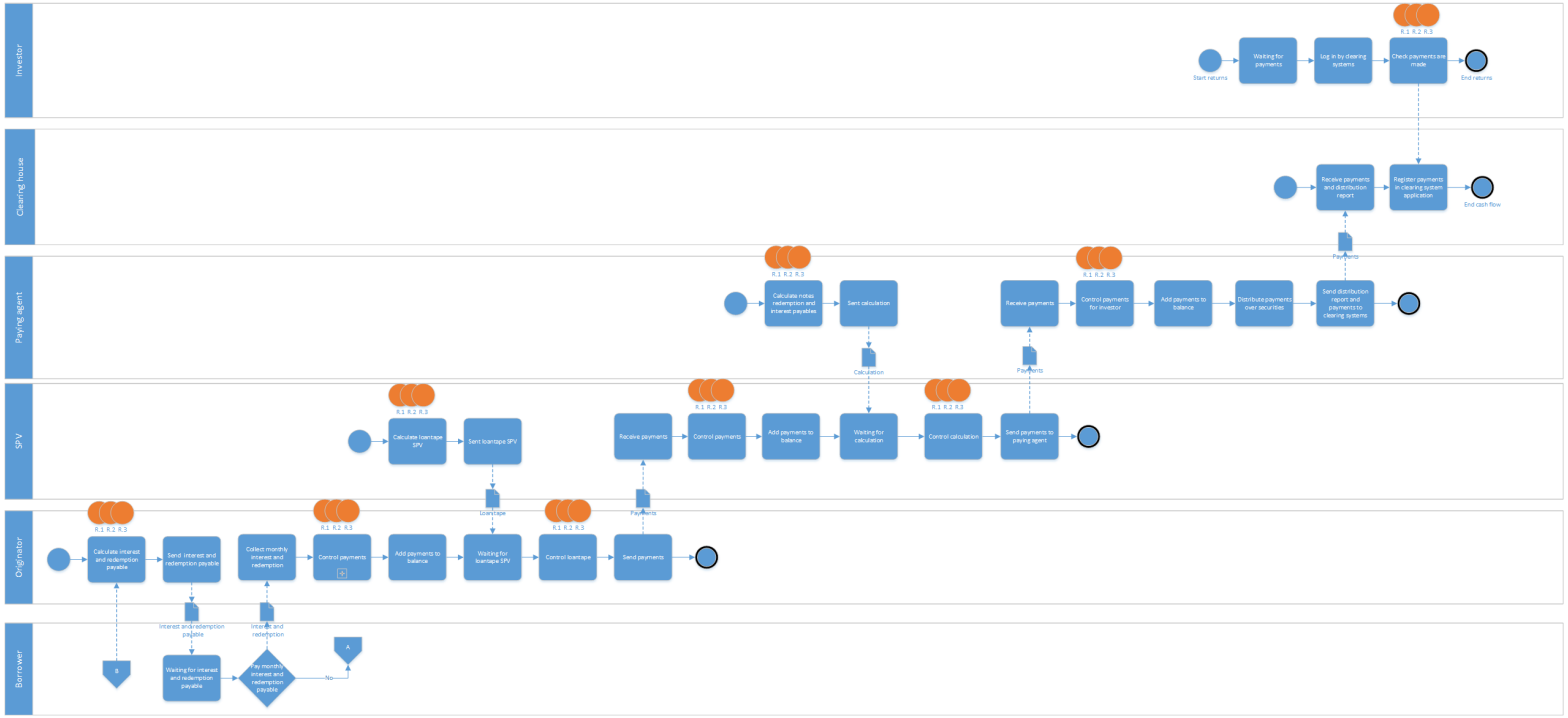


Figure 29: R-MBS payments

D.3 R-MBS default process

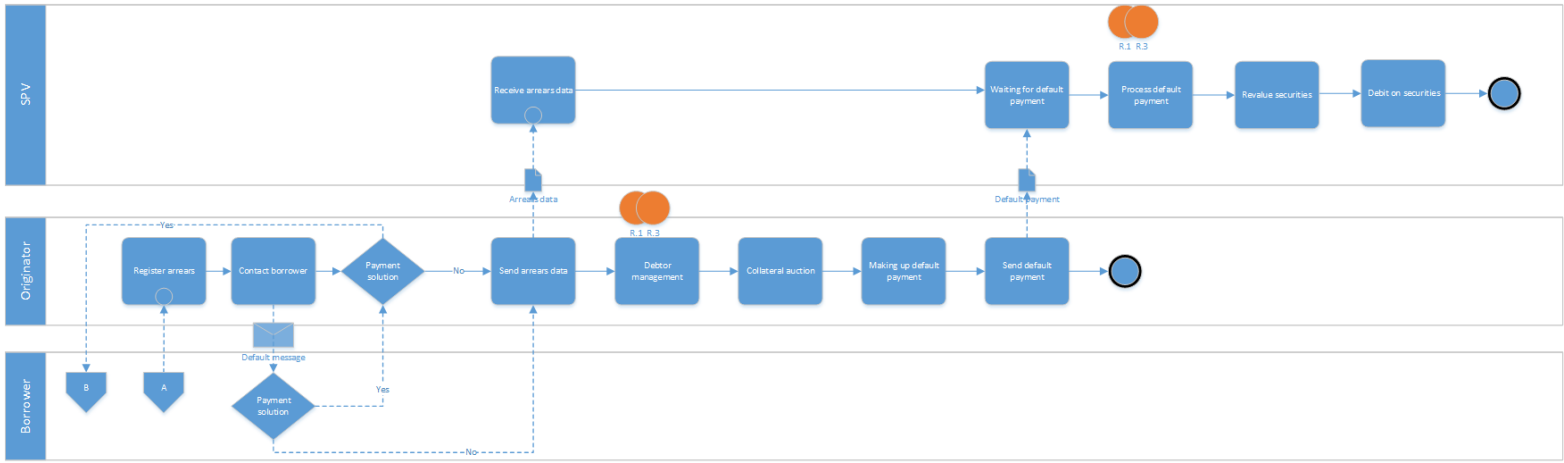
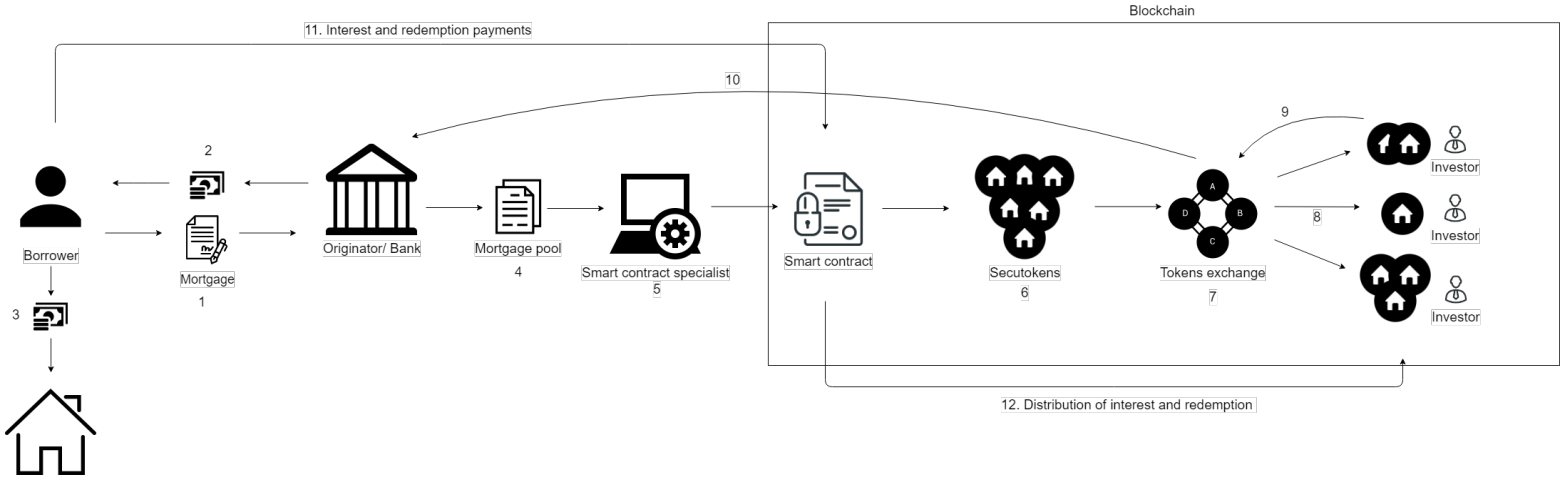


Figure 30: R-MBS default

E Simplified model



1. Origination of mortgage.
2. Bank fund the borrower.
3. Borrower fund the property.
4. Bank sends mortgage pool (multiple mortgages) to smart contract specialist (SCS).
5. SCS build smart contract with requirements of originator.
6. Smart contract creates secutokens, and keep track on the balance of investors.
7. Secutokens are issued on the token exchange.
8. Investors buy secutokens on the token token exchange.
9. One time cashflow to token exchange from investors.
10. One time cashflow, from token exchange to originator.
11. Monthly cashflow interest and redemption payments from borrower to the smart contract.
12. The smart contract does pre-programmed payments to the investors.

Figure 31: Simplified model

F Trade-offs

Process	Model design decision	Interview recommendation	Supporting literature
Tokenising the mortgage pool	Eliminate SPV by smart contract (SM).*	Expert C recomend to tokenise the mortgage pool with a smart contract. (CSPV)	*(Buterin et al. 2013)*
	Eliminate paying agent (PA) by SM.*	Many experts say that the transparancy of the blockchain and the immutability of SM is able to remove the controling practices of the PA. (PAYA)	*(DutchBlockchainCoalition 2017)*
	Eliminate clearing houses by SM.*	Expert F explains that the function of the blockchain to make payments and the function of smart contracts to distribute payments will eliminate the clearing houses. (FClear)	*(Buterin et al. 2013) (Nakamoto, 2009), (Tapscott &Tapscott, 2016)*
	Introduce new stakeholder.	No stakeholder found yet to fulfill this practice, based on researchers insights.	No literature, based on researchers insights.
	Eliminate credit agency.	In intervie C and F and discussion VB and VC is discussed that investor is able to value his token because of the transparancy of the blockchain. Mortgage data must then be listed on the secutoken.	No literature, supported by interviews.
Secutoken trading	Elimination of broker.	Expert C, recommend to remove the broker. Investors can make the trades themselves in this model. (EXCH)	No literature, supported by interviews.
	Exchange trade.	Expert C, recommend to trade secutokens on exchanges that are reachable for everyone. In the current system OTC trades are the partly cause of excludeing small investors says expert VA. (TRADESEC)	No literature, supported by interviews.
	Elimination of clearing house for settlement.	Expert A explains that settlement of trades will be much faster on the blockchain. (CLEAR)	*(mori, 2016)*
	Token trading process.	The trading process is based on the business prosess of the most commen token exchanges.	*bittrex.nl, bitstamp.com, bitfinex.com*
Secutoken storage	Creating this proces.	Storage of tokens becomes more important because they are more receptive to cyber crime. Expert F and VC emphisized this problem. (CUSTO)	*(Neuron, 2018)*
	Using online wallet.	This is discussed with expert F and VC. Large investors outsourch the storage of securities, and custodian companies are already transforming. (CUSTO)	No literature, supported by interviews.
	Token storage process.	The storage process is based on the business process of the online wallet platform: myetherwallet.	*myetherwallet.nl*
Secutoken payments	Elimination of SPV, PA, clearing house.*	see*	see*
	Using the corresponding cryptocurrency.	To overcome the problem that fiat currency can not be stored in SM the research assumes that everybody pays his mortgage in the corresponding cryptocurrency. This is discussed in the discussion with VD.	No literature, supported by interviews.
	Payment is stored in smart contract.	Paying by a smart contract is discussed in different interviews and discussions. (CASH, SMART)	*(Christidis and Devetsikiotis 2016), (Dutch-BlockchainCoalition 2017)*
	Distribution of interest and redemption payments by smart contract.	This process is based on the technology of the blockchain Neo and is varified in discussion VD.	*(Zhang and Hongfei 2018)*
Secutoken default process	Replace SPV for smart contract.	A smart contract can replace the SPV if conditions and calculations are pre-programmed. (SPV, SMART)	*(Buterin, 2013)*
	Originator take care of customer service.	There is a need for a customer service like in the current system because some defaults can be prevented. (CONBL)	No literature, supported by interviews.
	Devalue securities when default occurs.	When default occure the securities are revalued. (BOND, IWT)	*(Intertrust, 2016), (Angelides et al. 2011)*
Valuating the secutoken	Value like a R-MBS bond.	Expert D and F were enthousiastic about this idea when we discussed the valuation of the secutoken. (BOND)	No literature, supported by interviews.
	Take linear mortgage as collateral.	A linear mortgages as collateral is chosen for simplicity to discribe the principle of the valuation.	No literature based on researchers insights.
	Take interest rate into account.	Expert D pointed to the interest rate when we were discussing the valuation of a bond. (BOND)	(shapiro, 2008)

Table 9: Trade-offs

G Valuation

Mortgage		Interest	6%	Tokens	10
Year	10	Redemption	10%		
Mortgage value	100000	Redemption a month	10000		

Betaalde waarde onderpand	100000

Year	Mortgage value	Interest	Redemption	Market interest			Token value			
		6%	10%		Pnew	Pold	Value	Redemption	Interest	Yield
0	100000	0	0			10000	10000	0	0	
1	90000	6000	10000	2%	9000	9000	9000	1000	600	6%
2	80000	5400	10000	2%	8000	8000	8000	1000	540	6%
3	70000	4800	10000	2%	7000	7000	7000	1000	480	6%
4	60000	4200	10000	2%	6000	6000	6000	1000	420	6%
5	50000	3600	10000	2%	5049,505	5049,50495	5049,505	1000	360	6%
6	40000	3000	10000	1%	4049,505	4049,50495	4049,505	1000	300	6%
7	30000	2400	10000	1%	3049,505	3049,50495	3049,505	1000	240	6%
8	20000	1800	10000	1%	2049,505	2049,50495	2049,505	1000	180	6%
9	10000	1200	10000	1%	1049,505	1049,50495	1049,505	1000	120	6%
10	0	600	10000	1%	50	0	50	1000	60	6%
							Total	10000	3300	33,00%

Table 10: Value spreadsheet

H Research planning

	Week	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
2	Starting																											
3	Research design																											
4	Kick-off																											
5	Litarature study																											
6	Write draft Ch. 1& Ch. 2																											
7	PwC company visit																											
8	Planning interviews Ch3 & Ch.4																											
9	Litarature study Ch.3																											
10	Interviews Ch.3																											
11	Write draft Ch.3																											
12	Appointment **Marijn** BPMN modeling																											
13	Planning interviews Ch.4																											
14	Litarature study Ch.4																											
15	Interviews Ch.4																											
16	Write draft Ch.4																											
17	Midterm																											
18	Litarature study Ch.5																											
19	Design new BPMN model																											
20	Write draft Ch.5																											
21	Organise focus group																											
22	Write Ch.6																											
23	Write Ch.7																											
24	Greenlight																											
25	Process feedback																											
26	Write final																											
27	Prepare presentation																											
28	Thesis defence																											

Table 11: Research planning

I Codebook and data

	Codes	REMARK	A	B	C	D	E	F	VA	VB	VC	VD	0
2	**Securitization**												0
3	IMSEC	the importance of securitization			1								1
4	RISKSEC	Risks in securitization business process					1				1		2
5	CDO	About CDO's			1								1
6	CDOSQ	About CDO squar products		1		1							2
7	STASEC	Stakeholders in the securitization process			2	1				1			4
8	MMP	About how to monitor the mortgage pool				1	2	2			2		7
9	LAWSEC	About the laws round securitization		2	2	2		1	1			1	9
10	CONSEC	About the controls of securitization			1		1	1		1	1		5
11	TRADSEC	Over the counter trade				1				1			2
12	HAND	manually processes		1		1				1			3
13	TRUST	About the trustee			1								1
14	INBANK	About the investment bank			2								2
15	BORROW	About the borrower			1								1
16	SPV	SPV			2	1				1	1		5
17	BROKER	About function of broker								1			1
18	ADVISE	About the function of the advisor				1							1
19	AUDIT	Audit functions				1		1			1		3
20	CRAG	Credit agency				1		1			1	1	4
21	CUSTO	Custodian applicatie function						1	1		1		3
22	SWAP	Swap counterparty					1						1
23	CLEAR	Clearing houses		1				1					2
24	COMING	Commingling risk									1		1
25	EXCH	Exchange function				1	1		1				3
26	LIQ	Liquidity of RMBS		2	1	1	1					1	1	7
27	CREDIT	About selling credit risk in bonds AAA BB						1					1
28	CASH	About the payment proces (cashflow) in the securitization process		1	1	1	1		1	1			7
29	PAYA	Paying agent in securitization process								1			1
30	REA	Increase reliability		1									1
31	TIME	About transaction times		2	1	1						1	5
32	COST	Costs of securitization		1	1		1					1	5
33	**Blockchain**												0
34	BENFBL	About the benefits of blockchain in business processes		1	1							1	3
35	FACHAM	About factors that hamper blockchain implementation		2									2
36	CONM	About consensus mechanisms				1							1
37	CONBL	About the controls in a blockchain based system		1	2		1	2					6
38	REQBL	About the requirements by implementing blockchain				1		1					2
39	PRIPUB	Private or public blockchains				1					1		2
40	TROUGH	Throughput of blockchain				1							1
41	PREM	Premissionless or premissioned				1							1
42	SCALA	Scalability				1							1
43	**Combinding Blockchain and Securitization**												0
44	BOND	Give token valuation of bond					2		1	1		1		5
45	TOKO	About tokenizing securities				2	1		1				1	5
46	IWT	About the determiniton of the value of a token					1	1						2
47	INFOON	Information on the blockchain		1										1
48	PRSECBL	Information about the process combination		1		1	2					1		5
49	SMART	Smart contracts		1	2	1							1	5
50	LEAD	Who takes the lead at blockchain implementation		1	1									2
51	TRANS	Transparancy blockchain				1			1			1		3
52	DATA	Information about the data on the blockchain				3	1							4
53	MONPAY	About monthly payments									1		1	2
54	**Others**													0

Table 12: Codebook and data

J Interview protocols

J.1 Interview protocol 60 minutes

Welcome at the interview. The interview will help address the research questions of my thesis. The main question of my thesis is: How to redesign the business process of securitizing mortgage-backed securities and how does this business process looks like when blockchain plays an essential role in the ICT architecture?

1. Thank interviewee for taking the time to join the interview.
2. Mention that all the information and names of the participants will be held confidential.
3. Ask permission for recording the interview to facilitate note taking.

Introduction of the thesis:
Blockchain technology is changing the financial IT architecture. In my thesis I research the possibility to implement blockchain technology into the process of securitisation of mortgages. The mortgages are being converted in this process to mortgage-backed securities. This process is one of the practices banks fund mortgages. The important aspects that we will discuss in this interview, is the view of the interviewee on the process change, the factors that will hamper blockchain implementation, the complications in the securitisation process where blockchain technology can help to make the process more efficient, what the requirements are for the originator of the IT architecture. Furthermore, the opinion of the 'blockchain expert' is important.

1. What is your function within the company?
2. Can you describe your activities and responsibilities within the company?
3. If function is known: Consider your function as ..... in the company, can you describe your activities and responsibilities within the company?

Experience with securitisation
Securitisation is implemented all over the world by financial institutions to fund mortgages. This process has been pushed on the background after the financial crisis, but is still exercised by financial institutions. And with the current economic developments the demand for securitized products is increasing again.

1. What is the role of your work in the securitisation process and what are your experiences?
2. What are the most salient risks for investor and originator in the securitisation process? (Think of: screening credit worthiness of borrower, risk of not paying on time, risks of defaults, conflict of interests, etc.)
3. Securitized financial products were seen as high risk products after the financial crisis in 2008. Are the risks lower of the current way of securitisation? And what are the main causes of that?

4. What are the most problematic issues in the process of securitisation? (Think of: transaction time and costs, security issues, liquidity issues, privacy issues, etc.)

5. Are you known with CDO squared products? If yes, is the CDO squared process still a practice in the Netherlands?

6. Who are the stakeholders in this process and which stakeholder has the most influence on the securitisation process? (Who will take the main responsibility or who is paying for the ICT infrastructure)

Experience with Blockchain Technology
Blockchain technology is a subject that can help many financial processes in several ways: Cost reduction, transaction times, traceability (transparency), (Decentralization and a user controlled network). Several companies have already experimented with implementing a blockchain or already have (successfully) implemented blockchain technology.

1. Have you already participated in a blockchain implementation project? If yes, could you please elaborate on the implementation (in which process, how it went, benefits of blockchain in the process, critical points and issues, etc.)?

2. What could blockchain mean for your organization?

Securitisation on the blockchain
This thesis studies the opportunities blockchain could bring to the securitisation process of mortgages.

1. What kind of benefits will blockchain bring to the securitisation process?

2. What are the practical difficulties in the securitisation process that can be solved with blockchain technologies?

3. What would be the requirements (randvoorwaarden) of financial institutions to implement blockchain technologies into the process of securitisation? (Think of: Security, private or public blockchain, scalability, demanded throughput of the specific blockchain application)

4. What factors could hamper blockchain technology implementation into the securitisation process? (Think of all the issues blockchain can bring with it)

5. What kind of implementation of blockchain would you use? (Think of: blockchain 1.0,2.0,3.0 or different consensus mechanisms: Proof of work, proof of stake, delegated proof of stake, Byzantine fault tolerance, directed acyclic graph (Dag) Iota.)

6. What do you think is the minimal set of information needed on the securitisation blockchain? Dedicated to on and off chain information.

7. Do you consider to tokenize mortgages on the blockchain? If yes, how does this process looks like? (Information on tokens?, how to split tokens?, what kind of tokens? etc.) If no, next question.

8. How does a new blockchain-based securitisation process look like?

Closing questions

1. Do you have questions on this research or some more information that you would like to share?

2. Are there documents available that could support this study that you could share with me?

3. Can I contact you if I have further questions in the future?

Thank you very much for your time and information. This interview has helped me a lo to get a better understanding of the trajectory of blockchain implementation and the issues that are related to it. All answers to these questions will be held confidential. Furthermore, the results of the study will be provided to you if you want to.

J.2 Interview protocol 30 minutes

Welcome at the interview. The interview will help address the research questions of my thesis. The main question of my thesis is: How to redesign the business process of securitizing mortgage-backed securities and how does this business process looks like when blockchain plays an essential role in the ICT architecture?

1. Thank interviewee for taking the time to join the interview.

2. Mention that all the information and names of the participants will be held confidential.

3. Ask permission for recording the interview to facilitate note taking.

Introduction of the thesis:
Blockchain technology is changing the financial IT architecture. In my thesis I research the possibility to implement blockchain technology into the process of securitisation of mortgages. The mortgages are being converted in this process to mortgage-backed securities. This process is one of the practices banks fund mortgages. The important aspects that we will discuss in this interview, is the view of the interviewee on the process change, the factors that will hamper blockchain implementation, the complications in the securitisation process where blockchain technology can help to make the process more efficient, what the requirements are for the originator of the IT architecture. Furthermore, the opinion of the 'blockchain expert' is important.

1. Consider your function as ..... in the company, can you describe your activities and responsibilities within the company?

Experience with securitisation
Securitisation is implemented all over the world by financial institutions to fund mortgages. This process has been pushed on the background after the financial crisis, but is still exercised by financial institutions. And with the current economic developments the demand for securitized products is increasing again.

1. Who are the stakeholders in this process and which stakeholder has the most influence on the securitisation process?

Experience with Blockchain Technology
Blockchain technology is a subject that can help many financial processes in several ways: Cost reduction, transaction times, traceability (transparency), (Decentralization and a user controlled network). Several companies have already experimented with implementing a blockchain or already have (successfully) implemented blockchain technology.

1. Have you already participated in a blockchain implementation project? If yes, could you please elaborate on the implementation (in which process, how it went, benefits of blockchain in the process, critical points and issues, etc.)?

Securitisation on the blockchain
This thesis studies the opportunities blockchain could bring to the securitisation process of mortgages.

1. What are the practical difficulties in the securitisation process that can be solved with blockchain technologies?(Think of: transaction time and costs, security issues, liquidity issues, privacy issues, etc.)

2. What would be the requirements (randvoorwaarden) of financial institutions to implement blockchain technologies into the process of securitisation? (Think of: Security, private or public blockchain, scalability, demanded throughput of the specific blockchain application, Who will take the main responsibility or who is paying for the ICT infrastructure)

3. What factors could hamper blockchain technology implementation into the securitisation process? (Think of all the issues blockchain can bring with it)

4. What kind of implementation of blockchain would you use? (Think of: blockchain 1.0,2.0,3.0 or different consensus mechanisms: Proof of work, proof of stake, delegated proof of stake, Byzantine fault tolerance, directed acyclic graph (Dag) Iota.)

5. What do you think is the minimal set of information needed on the securitisation blockchain? Dedicated to on and off chain information.

6. Do you consider to tokenize mortgages on the blockchain? If yes, how does this process looks like? (Information on tokens?, how to split tokens?, what kind of tokens? etc.) If no, next question.

7. How does a new blockchain-based securitisation process look like?

Closing questions

1. Do you have questions on this research or some more information that you would like to share?
2. Are there documents available that could support this study that you could share with me?
3. Can I contact you if I have further questions in the future?

Thank you very much for your time and information. This interview has helped me a lo to get a better understanding of the trajectory of blockchain implementation and the issues that are related to it. All answers to these questions will be held confidential. Furthermore, the results of the study will be provided to you if you want to.

K Discussion protocol

Welcome at the validation discussion. The discussion will validate the model designed in this thesis. The main question of this discussion is: Do the expert discussions prove that the business process model created in this research is a viable option?

1. Thank interviewee for taking the time to join the discussion.
2. Mention that all the information and names of the participants will be held confidential.
3. Ask permission for recording the discussion or to facilitate note taking.

Introduction the thesis and discussion:
Blockchain technology is changing the financial IT architecture. In my thesis I research the possibility to implement blockchain technology into the process of securitisation of mortgages. The mortgages are being converted in this process to mortgage-backed securities. This process is one of the practices banks fund mortgages. The important aspects that we will discuss in this validation discussion, is the view of the interviewee on the current BPMN models and the designed blockchain-based securitisation process. Furthermore, the opinion of the 'blockchain expert' is important.

In discussion VA and VB the models of the current process (Figure: 15, Appendix: D.1, D.2, D.3) and the simplified model is discussed.

In discussion VC an VD the blockchain-based BPMN models (Figures: 16, 17, 18, 19 , 20) and the simplified model is discussed.

Questions asked to stir up the discussion were:

1. What is your first thought about this model?
2. Do you see any threats in this model?
3. Do you see improvements I have to make to this model?
4. Can this be a solution on the problem?
5. Do you think the environment of technology and regulatory are ready to implement those business processes?
6. Many stakeholders are cut away, do you think this would be a problem?
7. Do you consider a consortium, private or public blockchain?
8. Which consensus mechanism do you think is suitable for this network?
9. Do you think this model could increase liquidity of financial products? Increase transaction speed and lowering the transaction costs?
10. What do you think, what information is on the token?

Not all the questions where asked in the discussion, question only were asked when the discussion fell silent.

Closing questions

1. Do you have questions on this research or some more information that you would like to share?
2. Are there documents available that could support this study that you could share with me?
3. Can I contact you if I have further questions in the future?

Thank you very much for your time and information. This discussion has helped me a lot to validate my model and to get a better understanding of the trajectory of blockchain implementation and the issues that are related to it. All answers to these questions will be held confidential. Furthermore, the results of the study will be provided to you if you want to.