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Digital Twin Technology for Financial Industry

Master's Thesis (30 ECTS)

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Digital Twin Technology for Financial Industry

Abstract:
The focus of this thesis is the potential use cases of digital twins in the financial sector. This study explores these use cases, their benefits, and the challenges of the adoption to identify the value and impact this technology can bring to the financial services industry. As a result of interviews and thematic analysis, six potential use cases of digital twins were identified as well as four benefits and 6 challenges of digital twin incorporation. The main contribution of this research is a framework that can help practitioners and researchers understand how digital twins can be utilized in the financial sector.

Keywords: digital twin, financial sector, financial services, thematic analysis

CERCS: P170

Digitaalne kaksiktehnoloogia finantstööstusele

Lühikokkuvõte:
Käesoleva lõputöö fookuses on digitaalsete kaksikute võimalikud kasutusjuhtumid finantssektoris. Selles uuringus uuritakse neid kasutusjuhtumeid, nende eeliseid ja kasutuselevõtuga kaasnevaid väljakutseid, et teha kindlaks väärtus ja mõju, mida see tehnoloogia võib finantsteenuste sektorile tuua. Intervjuude ja temaatilise analüüsi tulemusena tuvastati kuus digitaalsete kaksikute võimalikku kasutusjuhtu ning neli eelist ja 6 väljakutset digitaalne kaksik kaasamisel. Selle uurimistöö peamine panus on raamistik, mis aitab praktikutel ja teadlastel mõista, kuidas digitaalseid kaksikuid saab finantssektoris kasutada.

Märksõnad: digitaalne kaksik, finantssektor, finantsteenused, temaatiline analüüs

CERCS: P170

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1 Introduction

Emerging Technologies such as big data, artificial intelligence, the Internet of Things and Systems, and nanotechnology are profoundly interconnecting the physical and digital worlds, which could significantly impact society's foundations through the power of digitalization and information technology (Savastano et al. 2019, Braccini and Margherita 2018). Due to the use of technologies, it is becoming more confident that in the upcoming years, many processes, such as the financial reporting process, the audition process, and the accounting profession will have to face the challenges of automation and digital transformation (Tiron-Tudor, Donțu, and Bresfelean 2022). Financial services have already gained benefits applying network-enabled connectivity and interactivity for more efficient information exchange, reduced operating costs, and improved efficiency in operations (Fan, Stallaert, and Whinston 2000).
Technology can help financial institutions build customer and channel loyalty, enhance customer relationships and increase customer, channel, and product profitability and market share (Siomkos and Tsiames 2006). Customer-centric financial technology services adoption is essential in achieving customer-centric objectives such as improving the customer experience (Gill, Bunker, and Seltsikas 2015). Emerging technology – a technology that demonstrates high potential but has not indicated its value or settled down into any consensus (Cozzens et al. 2010).
One thing that should be pointed out is that some emerging technologies have already shown value in many markets (e.g., artificial intelligence). Digital twin seems very promising, although it has not been explored in the financial sector; however, it has been used in a few industries such as manufacturing and aerospace industries, and its applications have not been widespread. The financial sector has not leveraged the capabilities of this emerging technology, and it is not clear what opportunities it brings.

Research Questions
This study aims to determine if the financial industry can benefit from DT technology. It examines how changes might be made possible by DT technology in the financial industry.
Therefore, The thesis discusses the following research questions:

RQ1: What are the potential use cases of DT in the financial industry?
RQ2: What benefits can the DT bring to the financial industry?
RQ3: What are the challenges of incorporating DT in the financial industry?

Contribution
The findings of this study present how DT technology can be used in the financial industry and what kind of impact it will bring. This study aims to explore the potential use cases of this technology in various financial services or processes. These findings can

benefit anyone who is involved in the financial sector. The contributions of this thesis are achieved by conducting interviews with representatives of the financial industry, analyzing the collected data by applying thematic analysis, and presenting the final results in the framework. This framework shows the use cases with descriptions and examples, the benefits, and the challenges they bring.

Structure of the Thesis

The thesis consists of 5 sections, including this one. The second section describes the main concepts of the DT technology and its main aspects, then go over financial services where this technology can be applied. This section also discusses the use cases of this technology in financial and other industries. The third section explains this research method in detail in this chapter. The fourth section demonstrates the results based on the findings for each research question. The fifth section finalizes this study and presents the conclusion.

2 Background

In this chapter, we look at DT technology and its main aspects, then go over financial services where this technology can be applied. Lastly, we describe the use cases of this technology in various industries.

2.1 Digital Twin

This section introduces Digital Twins (DT), its main components, and what enabled it.

The basic concept of the DT is based on the idea that a digital construct containing information about a physical system can be created as an entity on its own. This digital construct would be the “twin" of the information embedded within the physical system and is connected with that physical system through the whole lifecycle (Grieves 2016). DT provides the most accurate description of a planned or actual real-world object or process. The information can be distributed across multiple systems, but the information must be linked together to form a cohesive entity (Autiosalo et al. 2019).

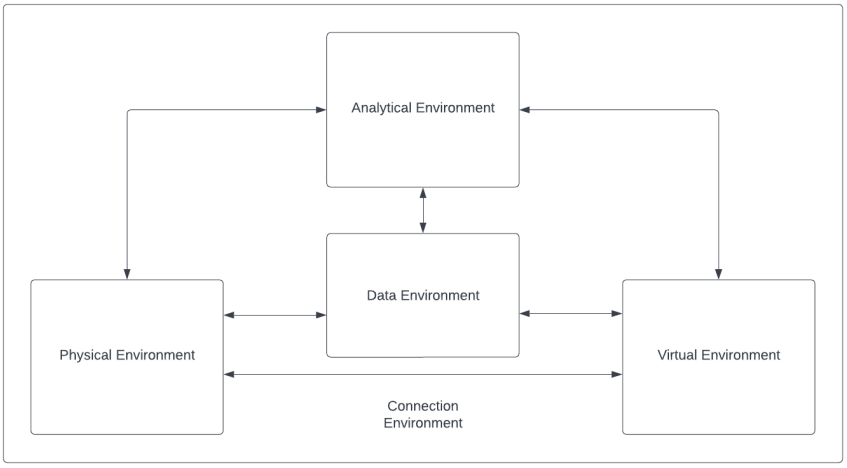

Figure 1: DT components.

DT incorporates five components, as shown in Figure 1, based on a five-dimensional DT model (Tao, Zhang, et al. 2018), the Physical Environment, the Data Environment, the Analytical Environment, the Virtual Environment, and the Connection Environment (Tao and Zhang 2017, Qi et al. 2021). The Data Environment stores the raw data about

other environments and their outputs. The Analytical Environment provides automatization, various computational services, and simulations, whereas the Physical Environment helps measure the DT's physical entity. Regarding the Visual Environment, it provides a DT itself to users as a visual model of the physical entity. Lastly, all these components are linked together through the Connection Environment that allows for composing multiple DTs (Grübel et al. 2022).

Virtual representations of real-world objects have been around for a long time; they needed a link to connect the two (Autiosalo et al. 2019). Various technologies enable DT: visualization technologies, verification, validation & accreditation (VV&A) technologies, optimization algorithms, simulation, retrospective technologies, modeling technologies, data analytics, fusion technologies, systems modeling, internet technologies, cyber-security technologies, etc. As so many disciplines and technologies enable DT, they were grouped into five categories: cognizing and controlling the physical world, DT modeling, DT data management, DT services, and connections in the DT (Qi et al. 2021).

Technologies for **cognizing and controlling the physical world** help to perceive (e.g., image recognition and measurement technologies), control (e.g., electrical control, programmable control, embedded control, and network control technologies), and understand (e.g., big data analytics technologies) the physical world (Qi et al. 2021).
Technologies involved in **DT modeling** are responsible for monitoring (e.g., appearance, shape, and attribute modeling), simulation (e.g., state, dynamic, and response modeling), prediction (e.g., rule extraction, description, association, and evolution), and verification (e.g., correctness, tolerance, availability, and result analysis) (Qi et al. 2021).

DT data management requires technologies that deal with data collection (e.g., sensory technology and API), data storage (e.g., big data technologies), data transmission (e.g., wire and wireless transmission technologies), data processing (e.g., data analytics and neural network technologies), data fusion (e.g., random methods and AI), and data visualization (e.g., geometry-based technologies, pixel-oriented technologies, layer-based technologies, image-based technologies, etc.) (Qi et al. 2021).

DT services include resources (enabled by on-demand, management, and encapsulation technology), knowledge (enabled by knowledge technologies), application (enabled by prognosis, diagnosis, simulation, etc.), and platform (enabled by platform architecture and business management technologies) services (Qi et al. 2021).

Connections in the DT provide real-time interaction among DT parts that require tech-

nologies such as protocol technologies and communication interfaces, human-computer interaction technologies(Qi et al. 2021).

DT has been defined in different ways depending on the industry. For example, DT is a digital equivalent of an object that can mirror its behavior and status or virtual replicas of real physical entities in Cyberspace (H. Yang et al. 2022). According to (Hehenberger and Bradley 2016), it is a virtual representation of physical processes or objects to visualize in a digital environment, ideally in real time. There is one more definition based on a literature review by Cor Verdouw et al. 2021 - "A DT is a dynamic representation of a real-life object that mirrors its states and behavior across its lifecycle, and that can be used to monitor, analyze and simulate current and future states of and interventions on these objects, using data integration, artificial intelligence, and machine learning". There are many definitions similar to those as mentioned above; hence, it was decided to use a generic definition in this work: "A live digital coupling of the state of a physical asset or process to a virtual representation with a functional output" (Boyes and Watson 2022). Since financial services are mostly digital, the study will focus on the process coupling to a virtual representation.

2.2 The Financial Industry and Digital Twin

This section presents the financial services industry and its potential relation to DT technology.

2.2.1 Financial Services

The financial services industry has been experiencing the recent emergence of technological innovations and looking for new ways to create successful business models, enhanced customer experience, and approaches that lead to services transformation (Gomber et al. 2018). For instance, the evolution of wireless technology and the widespread use of mobile devices have triggered the fast evolution of mobile commerce and financial services (Kousaridas, Parissis, and Apostolopoulos 2008). Financial technology, or FinTech, has affected the traditional financial industry by bringing innovations such as mobile payment, smart contracts, and blockchain technology (Anagnostopoulos 2018). Digital transactions allowed financial institutions to offer their customers various e-payment services and opportunities, such as debit cards, mobile banking, credit cards, and online banking systems (Premchand and Choudhry 2015). Smart Contract, enabled by blockchain technology, is a contract that uses artificial intelligence that engages directly with the stakeholders whose signatures are on the document, which is cost-effective (Younus, Muayad, and Abumandil 2022). According to Ravi and Kamaruddin 2017, robotics has already been used in banking to interact and communicate

with customers and provide a response to queries. As seen from the previously mentioned examples of different financial services supported by technology, technological innovations substantially change the financial industry's quality and productivity.

2.2.2 Relation to Digital Twin

The financial services industry is different from other industries such as manufacturing or retailing (Olazabal 2002) because financial institutions are connected to customers through a vast network of interrelationships that is more complicated and less linear than traditional manufacturing and retailing industries (Mulligan and Gordon 2002). Another difference is that most goods, such as cash, bills, contracts, and other documents, are just forms of information that can be represented digitally, which allows this industry to use technologies on a large scale (Zhu, Kraemer, and Dedrick 2004). Many processes and services in the financial sector can leverage DT technology. For instance, activities resulting in financial transactions have to come from simulation to model the financial behavior associated with specific processes, then use the simulation output to determine the entire scope of counterpart financial transactions for the relevant production transactions before using the combined production and financial transactions to calculate the data required for income statement generation (Murphy et al. 2020). DTs and their real-time simulation capabilities have already been used for continuous control of processes (Noskievič and Walica 2022a). According to (Noskievič and Walica 2022b), robo-advisors, brought by technological innovations, offer a valid alternative for seeking investment advice, especially among those investors who worry about conflicts of interest during human financial advisory. This service can obtain advantages from using DTs, such as increasing the efficiency of the personal financial management process and customers' competency (Anshari, Almunawar, and Masri 2022).

2.3 Use Cases of Digital Twin in Industries

In this section, we talk about the use cases of DT such as simulation and optimization of the production, health digital twin, and farm management in various industries: manufacturing, healthcare, and agriculture.

These days in highly competitive markets, where mass customization of products and the increasing significance of software components present new challenges: digitalization in manufacturing is viewed as a chance to achieve greater levels of efficiency (Uhlemann, Schock, et al. 2017). In this field, DT technology enables the simulation and optimization of the production system, including its logistical aspects, as well as detailed visualization of the manufacturing process from individual elements to the entire assembly (Kritzinger et al. 2018). This technology tends to encourage disciplines of manufacturing systems such as production planning and control (Rosen et al.

2015), maintenance (D'Addona, Ullah, and Matarazzo 2017, Susto et al. 2014), layout planning (Uhlemann, Lehmann, and Steinhilper 2017) to bring higher competitiveness and efficiency. For instance, production planning and control can be improved with production units automatically planning and executing orders and enhanced decision support through detailed diagnosis and planning of orders based on statistical assumptions (Rosen et al. 2015). DT can serve as a main point where collected data is stored, processed, and analyzed. Examples of such data include a patient's medical history, professional recommendations from medical experts, and past medical case studies of a similar nature. This provides the DT with vital information to process and give recommendations on the scaffold design with regard to its shape, size, geometry, and even the material to be used (Haw, Sing, and Liu 2022), which is shown in Figure 2.

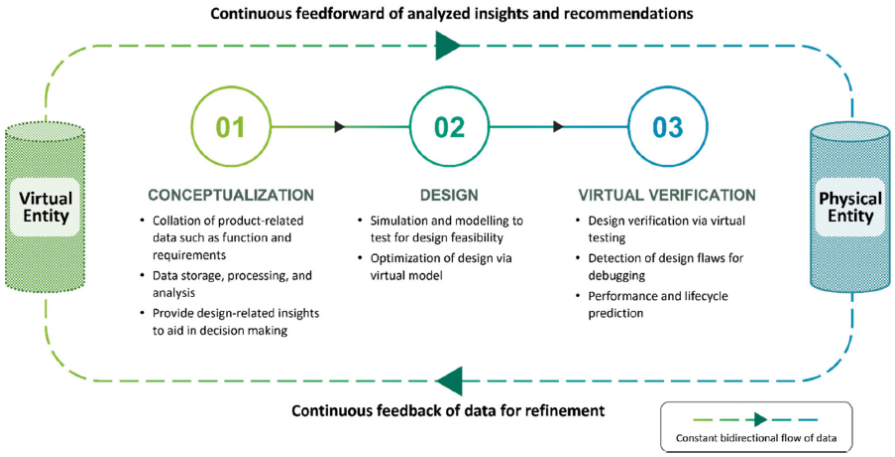

Figure 2: Implementation of DT in product design (Haw, Sing, and Liu 2022).

Although DTs have been used for a while, especially in manufacturing, the concept of "health digital twin" (HDT) has recently entered healthcare. In this field, the appropriate use of DTs can bring tremendous advancement in precision medicine, clinical trials, and public health. There were found 18 patent applications, of which 73% were from companies and 27% were from academia (Coorey et al. 2022). HDT technology includes two main concepts: cyber-physical systems (CPS) and closed-loop optimization (CLO) (Barricelli, Casiraghi, and Fogli 2019). CLO uses real-time data to monitor, diagnose, predict disease, and optimize treatment. Data collected from the physical twin can be used to estimate and then predict patient reaction to the medication, behavior change, and environmental aspects (Coorey et al. 2022). HDT could also be used for a cost-effective synthetic control arm for clinical trial data (G 2021). HDT technology, combining AI-powered analysis and real-time data collection, can bring health

care closer to truly personalized medicine. In Figure 3, a DT model for the healthcare context is proposed.

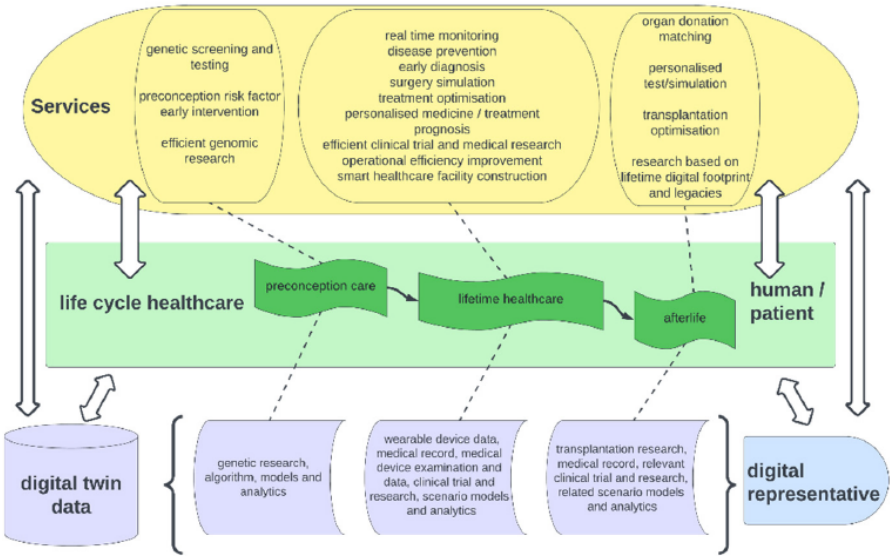

Figure 3: DT model in healthcare (Hassani, Huang, and MacFeely 2022).

Making agriculture intelligent and sustainable is crucial since food production is constantly increasing, and approximately 32% of the food produced is wasted (Schuster and Torero 2016). According to Cor Verdouw et al. 2021, the first application of DTs in farm management was discovered by CN Verdouw and Kruize 2017, where physical objects had real-time and remotely connected digital equivalents enabling farmers to act immediately in case of deviations. Traditional farming is based on weather, farmer's experience, and human observations, but with the incorporation of DTs farming in the future will be based on real-time data and data analytics which can increase the return from agricultural resources (Neethirajan and Kemp 2021). The management of animal welfare and the production of animal products have been improved with the usage of precision livestock farming (PLF), where an essential tool is sensors. Therefore PLF can be a starting point for the DT technology implementation in livestock farms (Neethirajan 2017). The usage of DT in greenhouse horticulture can free it from physical proximity and enable remote and automated performance, monitoring, management, and coordination of greenhouse procedures by different stakeholders, which is shown in Figure 4 (Cor Verdouw et al. 2021).

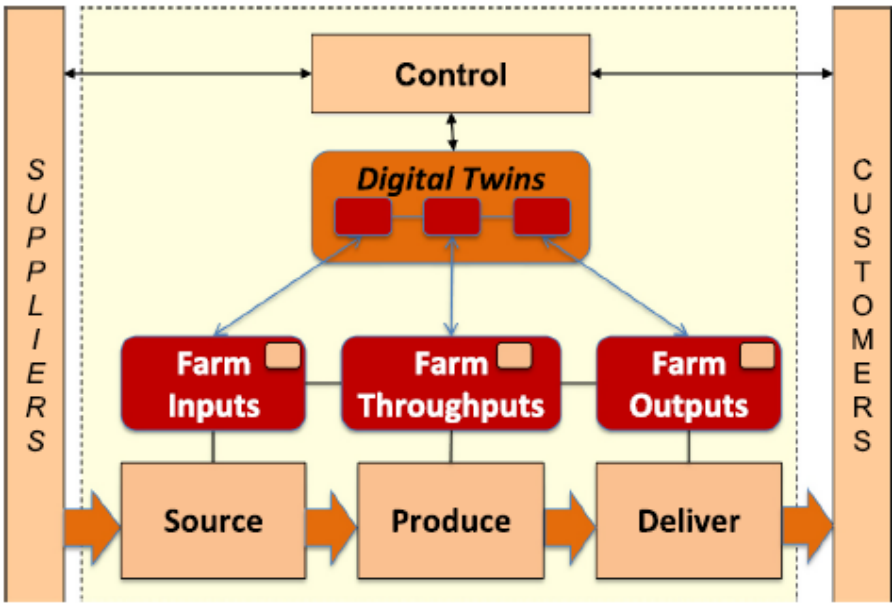

Figure 4: Virtual control of farming enabled by DT (Cor Verdouw et al. 2021).

Scientific papers mentioning the use cases of DT in the financial sector were not found during the literature review.

2.4 Related Work

This section gives an overview of the related works that explored DTs' use cases and applications in different industries.

Alva, Biljecki, and Stouffs 2022 documented the use cases of the district-scale urban DT applications and platforms, the purpose of which is to model, manage and analyze smart cities' components such as buildings, transportation, energy, water, utility, and infrastructures. Their method was the literature review and used papers from 2017 to 2021. They created a classified inventory and conceptual architecture for developing an urban DT that stakeholders in companies, government agencies, and academia can find helpful. Guo and Lv 2022 explored applications of the DT in multiple fields such as industrial manufacturing, model construction, plant management, medical field, smart cities, space field, etc. Then they explained the DT's needs and development focus in those fields.

Madubuike, Anumba, and Khallaf 2022 employed a systematic literature review, including thematic analysis, to review the development and implementation of DT technology

in the construction industry, comparing its use with other industries. They identified limitations of the existing and upcoming applications and highlighted the importance of DT use in the construction sector. De Benedictis et al. 2022 analyzed the scientific literature on DT use cases in healthcare, identified four primary categories, and proposed a DT conceptual architecture. Based on this architecture, they implemented CanTwin, the DT of the canteen service, to manage people flow and to monitor social distancing in the context of the COVID-19 pandemic.

Simões et al. 2022 presented a series of use cases demonstrating the role of a DT in various phases of the industrial product lifecycle. They discovered that the 3D web enables visualization and interaction with DTs in production scenarios. Wang et al. 2022 described a particular DT application in the space industry by conducting experiments and evaluation. They eventually proposed a set of standardized experimental processes for simulating the full-life test cycle of space microdebris that produces accurate data with a small experimental cost.

All these works have focused on DT applications in various industries but the financial sector. Therefore, this thesis will explore potential use cases of this technology in the financial services industry.

3 Methodology

This section represents the research process of the thesis and details how data was gathered and analyzed to answer the research questions.

Planning and designing a research strategy is necessary to find possible answers to the research questions. The research method for this thesis began by collecting and studying some background information regarding the usage of DT in various industries; after that, the research questions were decided. The data is collected by conducting semi-structured interviews and asking open-ended questions to those who are either involved in the financial sector or are familiar with DT Adeoye-Olatunde and Olenik 2021. After data collection, thematic analysis is carried out to extract research results Terry et al. 2017.

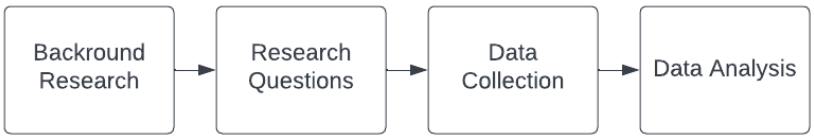

Figure 5: Overview of the research

Background Research:
This part of this research analyzes DT, its various definitions, and its main aspects. The structure and the definition of DT are defined for this study. The financial services and their relation to DT are researched. Lastly, the use cases of this technology in various industries are explored. The purpose of background research is to have sufficient information about DT and its usage status in different industries, including the financial one. During this stage, over fifty scientific papers were studied and used in this research.

Research Questions:
After background research, research questions are defined, which are the following:
RQ1: What are the potential use cases of DT in the financial industry?
RQ2: What benefits can the DT bring to the financial industry?
RQ3: What are the challenges of incorporating DT in the financial industry?

RQ1 is the central question of this research that explores how DT can be used in the financial sector. The purpose of **RQ2** is to define the potential value of using DT in this

industry. **RQ3** aims to determine the obstacles financial institutions might face using DT in their services and processes.

Data Collection:
The conduction of semi-structured interviews will provide data using open-ended questions to those who have expertise in the financial services industry or are familiar with DT. The rationale for choosing the semi-structured interview technique is to encourage the interviewees to freely discuss their views on how DTs can be used in the financial sector Fylan 2005. This method with open-ended questions will allow us to adjust our questions depending on the field the interviewee is involved. The gathered data will be analyzed to identify results and answer research questions.

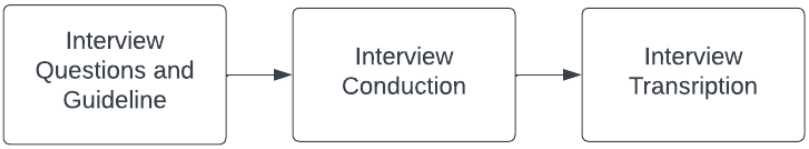

Figure 6: Overview of the data collection

Interview questions (IQs) are based on research questions. **IQ1** and **IQ3**, the purpose of which is to explore possible applications of DT technology in the financial services industry and what benefits it can bring, are derived from **RQ1** and **RQ2** respectively.**IQ2**, **IQ4**, **IQ5** and **IQ6**, which aim to determine challenges for DT incorporation in this sector and how much it can take till that, are based on **RQ3**. All the interview questions are presented in Appendix III.

IQ1: How can DT technology be used in the financial sector?
IQ2: What would be the motivation for financial institutions to use DT?
IQ3: How can DT technology improve the processes in financial institutions?
IQ4: What are the obstacles for financial institutions to incorporate DTs?
IQ5: How soon can financial institutions incorporate DT technology?
IQ6: What are the prerequisites for DT to enter the financial sector?

The search for suitable participants and the following establishment of contact was accomplished via a social business platform to find appropriate interviewees. The list of interviewees with their backgrounds is presented in Table 1. An interview guideline,

which is presented in Appendix I, was developed to focus on and structure the interviews and to ensure thematic comparability. It consists of the following parts: 1) welcome the interviewee and introduce the interviewee to the research topic, 2) ask for verbal consent and start the recording, 3) ask interview questions, 4) answer clarifying questions, if any, and 5) stop the recording and finalize the interview. All interviews are conducted online via Zoom and recorded to increase the reliability of the answers. Interviewees must sign a consent form, which is presented in Appendix II, before the interview or give verbal consent during a recording. The interviews take 30 to 40 minutes and follow a specially developed interview guideline. All video recordings are transcribed to process them for subsequent analysis and further deleted.

ID	Industry	Occupation	Level of Expertise
INT01	Tech Industry	Technology Journalist	1.5 years
INT02	Infrastructure and Built Environment	Infrastructure and Technology Advisor	10 years
INT03	Mechatronics and Electrical Drives	Professor	3 years
INT004	Digital Transformation of the Built Environment	Independent Consultant	5 years
INT05	Digital Transformation of the Built Environment	Strategic Advisor	5 years
INT06	Social Digital Twin	PhD, Research and Development Director	3 years
INT007	Digital Transformation of the Built Environment	PhD, Researcher	3 years
INT08	Information Technology and Financial Services	Tech Lead and Advisor	2 years
INT09	Energy Resilience and the Built Environment	PhD, Researcher	7 years
INT10	Architecture and Smart Cities	Professor	5 years
INT11	Information Technology and Emerging Tech	Advisor and Executive	6 years
INT12	Information Technology	PhD, Researcher	5 years

Table 1: Interviewees

Data Analysis:
The collected data is analyzed by highlighting primary responses and interpreting and extracting keywords and critical quotes. Use cases of DTs are established on the analyzed data to describe better the usage of DT technology in the financial sector. And then, a use case framework is created to organize these use cases. The thematic analysis approach is a flexible method of qualitative analysis that enables us to generate new insights and concepts derived from data Alhojailan and Ibrahim 2012. The overview of the data analysis is presented in Table 7.

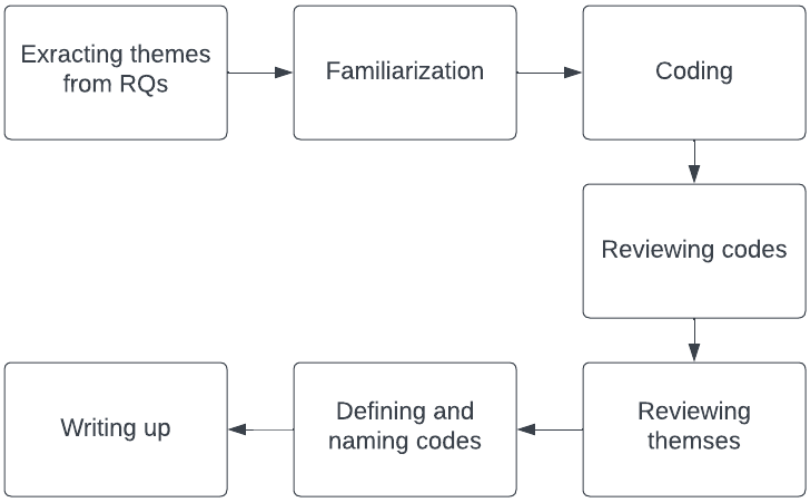

Figure 7: Overview of the data analysis

First of all, themes are created based on the research questions. One or two themes are derived from each research question. For instance, a theme "Use case" is derived from **RQ1** and "Benefits" from **RQ2**.

The second step is to get to know our data. It's essential to get a thorough overview of all the collected data before analyzing individual items. In this study, twelve transcripts were familiarized.

The next step is data coding, highlighting sections of transcripts – usually phrases or sentences – and coming up with shorthand labels (codes) to describe their content. Then all the codes are looked over, and patterns among them are defined. For example, potential use cases of DT, such as better ESG reporting, data-driven decision-making, data

visualization, transparency between institutions and customers, and prediction based on simulation, were mentioned several times in some interviews, which means those should be coded.

Then reviewing and refining the codes would be a natural step to take to identify any overlaps or redundancies. Sub-codes might emerge during this process. For example, there are use cases related to customer service which can be categorized into three sub-codes such as "Transparency", "Enhancement" and "Fraud Prevention".

Reviewing themes includes making sure they are useful and accurate data representations and splitting them up, combining them, discarding them, or creating new ones. Several codes are combined into a single theme. For example, all the codes indicating use cases, such as customer service or regulations reporting, are part of a theme "Use cases". Themes "Challenges" and "Prerequisites" are merged into a theme "Challenges and Prerequisites" because of the correlation of their codes.

Defining and naming codes involves formulating precisely what each code means and figuring out how it helps to understand the data. Naming codes involves creating a short and easily understandable name for each of them. For example, the theme "Use Cases" includes 7 codes with generalized and refined names such as "Risk Management", "Compliance and Regulations" and "Operational Efficiency" as they clearly represent all the data extracted from transcripts regarding use cases.

Text refinement and improvement of the articulation of the ideas were done with the help of tools such as Grammarly[1] and text-generating artificial intelligence such as ChatGPT[2] respectively.

Finally, the last step is to write up our data analysis, and the conclusion explains the main takeaways and shows how the analysis has answered our research questions.

[1]For more information about Grammarly:`https://www.grammarly.com/grammarlygo`

[2]ChatGPT is developed by OpenAI. For more information about ChatGPT and OpenAI: `https://openai.com`

4 Results

This section introduces the results of this study, which are the following: use cases of the DT in the financial sector, potential benefits brought by the use of the DT, and the challenges that are to be faced by the financial institutions incorporating DT.

4.1 Use cases

RQ1 is about the use cases of DT in the financial sector. Six potential use cases were found, in descending order, namely "Customer Service", "Operational Efficiency", "Risk Management", "Trading and Investment", "Asset Management", and "Compliance and Regulations". All these use cases are enabled by the transparency provided by DT as it is essential to provide open and clear access to information and data related to their systems and processes. More specifically, it can provide real-time data to various financial stakeholders such as investors and regulators. The number and the kind of use cases mentioned by interviewees are represented in Table 2. The summary of use cases with description and example is shown in Table 3.

Interviewee	CS	OE	RM	TI	AM	CR
INT01	2	0	0	0	1	0
INT02	1	1	1	0	1	1
INT03	1	0	1	1	0	0
INT04	1	1	1	2	1	1
INT05	0	1	0	0	0	0
INT06	1	1	0	0	1	0
INT07	0	1	1	0	0	0
INT08	0	0	1	0	1	0
INT09	1	1	0	1	0	0
INT10	0	0	1	1	0	0
INT11	1	0	0	0	0	0
INT12	0	1	0	0	0	0
Total	8	7	6	5	5	2

Table 2: Number of use cases mentioned by interviewees

Customer Service (CS) is one of the areas where DT can be used in the financial sector. CS is the interaction between financial institutions and customers, such as answering questions and providing support and information about financial products and services. There are three ways how DT can be applied here: performance analysis powered by DT to provide insights into where the customer service can be improved - the

improved customer support use case, providing more personalized services and new products for customers - the enhanced customer service use case, and protecting from fraud customers - the fraud prevention use case. Transparency is a central component in the listed use cases meaning they are enabled by access to the real-time data from DT.

Financial institutions can manifest the improved customer support use case by having the DT of the customer journey and simulating the customer's financial circumstances and identifying the core cause of the issue. A bank, for example, can use a customer's digital replica to detect when they are approaching their credit limit and offer them alternatives to prevent exceeding their limit or a credit line increase. This service can be provided in real-time with the help of the modeling abilities of DT. **INT02** commented: "Giving transparency in terms of what's actually happening, what is being reported through DT".

A financial organization can better understand each customer's individual requirements and preferences by generating DT of their profiles and adapting products and services to those particular needs. This is how the enhanced customer service use case can be implemented. This organization, for instance, can build a DT of a customer's journey who is a small company owner. The DT can provide insights into the customer's unique wants and preferences by evaluating data on the customer's financial transactions, business performance, etc. Based on this data, the organization can provide a credit line with flexible repayment terms with reduced interest rates. With regard to this, **INT09** said, "If they're selling financial products, they use DT to understand buying patterns, so then you know what products they should be pitching and where they should be focusing their efforts.".

The fraud prevention use case refers to building a digital replica of a customer's account is one of the ways DT can be used to detect fraud. This digital replica can be used to monitor an account and its transaction history in real-time, utilizing algorithms and machine learning models to spot patterns and abnormalities that might suggest fraudulent action. For example, a customer's DT can show abnormal login activity like trying to access the account from an unknown device using the visualization capabilities. **INT01** remarked: "if you're going to approve a credit card transaction, you're going to want a better fraud model".

Operational Efficiency (OE) can be manifested by a financial institution through the improvement of its operations, shortening waste, and streamlining procedures in order to achieve reduced costs and better resource utilization. There are two use cases regarding this. The first one is the process improvement use case. For example, financial institutions can create DT of the operational processes and use them to simulate vari-

ous scenarios and identify potential bottlenecks and other areas for improvement. The second use case - resource management can optimize resource allocation by developing DT of the financial institution's physical assets and processes. Transparency is a key component of the use cases outlined here as well.

A financial institution such as a bank can improve its loan approval process by creating a DT of this entire process that models everything from application to the final acceptance or rejection. Using this DT, they simulate various scenarios and test the result of changes in this process. They can extract data on loan history from DT and analyze it using machine learning algorithms to understand ways that can be used to improve this process. **INT06** said: "You can simulate different scenarios and see what will be the best result for your company".

A bank, for example, has many branches in different regions, each with a varied degree of client activity and staffing requirements. The bank can test different situations and allocate resources more efficiently by creating DT for each branch. Having a set of connected DT of these branches provides extensive insights to help with defining what branches have increased consumer traffic and demand additional employees during peak periods. **INT05** said: "If you can get an ecosystem of connected DT, then what you can do is understand the system better and then intervene effectively".

Risk Management (RM) - the process of discovering, assessing, and controlling risks to a company's capital and profitability. These risks arise from a range of causes, including financial insecurity, legal liability, technological challenges, strategic management mistakes, etc. By developing virtual replicas of financial processes and systems, DT can help in risk management by allowing simulations and analysis of potential problems before they arise. There are two use cases that can be implemented in the financial sector - risk analysis and predictive analytics where transparency is the foundation.

A financial institution can analyze large amounts of data collected by DT to identify patterns, make predictions, and evaluate risks using data mining, machine learning, and other analytical techniques. For instance, a financial firm might use predictive analytics to predict a loan applicant's chance of default based on a variety of criteria such as credit history, income, and work status. **INT07** said: "Digital Twin of a whole banking system, and you can see the processes so that you predict, simulate, even diagnose potential issues within it before they occur".

DT can spot patterns and abnormalities in data using machine learning algorithms, predict possible dangers in real-time, and assist financial institutions in taking measures to mitigate those risks. A financial firm, for instance, can create DT of a customer to

simulate various scenarios, such as changes in income or important life events such as marriage or retirement, and evaluate the potential impact on the customer's capacity to repay loans or manage their financial responsibilities. This data can be utilized to inform the firm's lending and risk management decisions for that specific client. **INT04** stated: "Some of the credit agencies are essentially creating DT of people and how they act to give them better information to make decisions on whether somebody is a suitable candidate for a certain type of credit".

Trading and Investment (TI) refer to the purchase and sale of financial items such as stocks, bonds, and derivatives in order to generate profits for investors or customers. The usage of DT in trading and investment can assist financial firms in making better investment decisions and more effectively executing trades. There are two use cases such as automated trading - developing and testing algorithmic trading strategies and market analysis - analyzing market trends and identifying potential opportunities for investment.

Automated trading use case: DT can be used to monitor the performance of trading algorithms and adapt them in response to changing market conditions, allowing traders to make better better decisions and optimize their profits. Financial institution can utilize DT of the stock to model how the stock price might respond in various situations and market conditions to develop an algorithmic trading strategy for that stock. Then the algorithm can predict that the stock is likely to grow in price because of positive return outcomes, and execute a buy order accordingly. Testing different scenarios with this stock and observing how it responds to them allows a financial firm to make better trading decisions. **INT09** explained: "Once you have that information, you have to develop different types of models. And then, you can plug that back into your model and then see what the ultimate outcome will be".

Market analysis use case: financial institutions can create virtual replicas of financial markets, which can be analyzed using advanced algorithms and machine learning techniques using DT. A financial organization, for instance, can build DT of a specific stock market and use predictive modeling and machine learning algorithms to evaluate market trends and discover patterns that would not be clear from raw market data. This data can then be utilized to advise investing strategies and assist traders in making better decisions. **INT03** gave an example: "Monitoring what's going on in the markets, analyzing them and then provide services like prediction of prices".

Asset Management (AM) is the procedure of monitoring and managing a company's assets in order to optimize its value while minimizing risk. Physical assets such as equipment and property, financial assets such as stocks and bonds, and intangible assets

such as intellectual property and goodwill are examples of assets. With the help of DT financial institutions can get real-time data and insights about assets, which can help to optimize their performance, increase their lifespan, and reduce maintenance expenses.

Predictive maintenance is one potential use case. A bank, for example, can monitor ATM machines in real-time, detecting potential problems before they happen. This can include monitoring the state of the ATM's various components, such as the cash dispenser, card reader, and network connectivity, as well as utilizing machine learning algorithms to evaluate usage patterns and discover anomalies. This bank can repair or replace it during off-peak hours by predicting when it's needed to prevent downtime and ensure customers always have access to operating ATMs. **INT04** said:"Having a DT will allow us to for example, extend the life of the asset because we're really sure what's happening to it, because all that data is held within the digital twin".

Compliance and Regulations (CR) use case is manifested in the financial sector via submitting required information and data to regulatory bodies and proving that the regulations are met. By providing a more accurate and effective approach to collecting and analyzing data, DT can assist financial institutions with regulatory reporting. Transparency is a key feature here, too, since it requires a lot of data collection from different sources. For example, a financial institution can use DT of its operations to observe and track in real-time its compliance with regulations related to the General Data Protection Regulation (GDPR) and Payment Card Industry Data Security Standard (PCI DSS) requirements. DT can provide automatic data collection and aggregation from various sources within a financial institution, like customer information and financial statements. **INT02** stated: "Digital twins will allow investors and financial markets comply with those regulations in a better way".

Name	Description	Example
CS	It is the interaction between financial institutions and customers, such as answering questions and providing support and information about financial products and services.	Financial institutions can manifest the improved customer support use case by having the DT of the customer journey and simulating the customer's financial circumstances and identifying the core cause of the issue. A bank, for example, can use a customer's digital replica to detect when they are approaching their credit limit and offer them alternatives to prevent exceeding their limit or a credit line increase.
OE	It can be manifested by a financial institution through the improvement of its operations, shortening waste, and streamlining procedures in order to achieve reduced costs and better resource utilization.	A financial institution such as a bank can improve its loan approval process by creating a DT of this entire process that models everything from application to the final acceptance or rejection. Using this DT, they simulate various scenarios and test the result of changes in this process. They can extract data on loan history from DT and analyze it using machine learning algorithms to understand ways that can be used to improve this process.
RM	It is the process of discovering, assessing, and controlling risks to a company's capital and profitability. These risks arise from a range of causes, including financial insecurity, legal liability, technological challenges, strategic management mistakes, etc. By developing virtual replicas of financial processes and systems, DT can help in risk management by allowing simulations and analysis of potential problems before they arise.	A financial institution can analyze large amounts of data collected by DT to identify patterns, make predictions, and evaluate risks using data mining, machine learning, and other analytical techniques. For instance, a financial firm might use predictive analytics to predict a loan applicant's chance of default based on a variety of criteria such as credit history, income, and work status.

TI	It refers to the purchase and sale of financial items such as stocks, bonds, and derivatives in order to generate profits for investors or customers. The usage of DT in trading and investment can assist financial firms in making better investment decisions and more effectively executing trades.	Market analysis use case: financial institutions can create virtual replicas of financial markets, which can be analyzed using advanced algorithms and machine learning techniques using DT. A financial organization, for instance, can build DT of a specific stock market and use predictive modeling and machine learning algorithms to evaluate market trends and discover patterns that would not be clear from raw market data.
AM	It is the procedure of monitoring and managing a company's assets in order to optimize its value while minimizing risk. Physical assets such as equipment and property, financial assets such as stocks and bonds, and intangible assets such as intellectual property and goodwill are examples of assets. With the help of DT financial institutions can get real-time data and insights about assets, which can help to optimize their performance, increase their lifespan, and reduce maintenance expenses.	Predictive maintenance is one potential use case. A bank, for example, can monitor ATM machines in real-time, detecting potential problems before they happen. This can include monitoring the state of the ATM's various components, such as the cash dispenser, card reader, and network connectivity, as well as utilizing machine learning algorithms to evaluate usage patterns and discover anomalies. This bank can repair or replace it during off-peak hours by predicting when it's needed to prevent downtime and ensure customers always have access to operating ATMs.
CR	DT will allow investors and financial markets to set their ESG goals, track them better, and actually show compliance.	Investors and financial institutions have to report what sort of investments they have made along with what sort of impact on the environment and society they have. That's where ESG and regulations come in. With DT, they can set ESG goals and comply with the regulations in a better way.

CR	It is manifested in the financial sector via submitting required information and data to regulatory bodies and proving that the regulations are met. By providing a more accurate and effective approach to collecting and analyzing data, DT can assist financial institutions with regulatory reporting.	A financial institution can use DT of its operations to observe and track in real-time its compliance with regulations related to the General Data Protection Regulation (GDPR) and Payment Card Industry Data Security Standard (PCI DSS) requirements. DT can provide automatic data collection and aggregation from various sources within a financial institution, like customer information and financial statements.

Table 3: Summary of Use Cases

4.2 Benefits

RQ2 is about the benefits of DT usage in the financial sector. There are four ways in which the financial sector can benefit from DT, in descending order: "Data-driven Decision Making", "Data Visualization", "Data Quality and Management", and "Risk Mitigation". The number and the kind of benefits mentioned by interviewees are represented in Table 4. The summary of benefits with description and example is shown in Table 5.

Data-driven Decision Making (DDM): It is basically about the ability to be data-driven and facts-driven to have a better understanding and assessments of risks and more accurate predictions. Some financial institutions can gain an advantage over others with this DT. **INT05** stated: “There clearly is a value in having better decisions faster, making better decisions faster than competitors”.

Data visualization (DV): Visualizing data can provide better insights about the system, its processes, and its impact. There is a benefit for financial institutions complying with regulations. **INT04** explained: “DT’s visualization feature gives you the ability to prove that you’ve met regulations, that you’ve met compliance, that you’ve met ESG.” Moreover, it can benefit their customers. For instance, **INT03** said: “We can show data to the customer that is usually hidden”.

Data quality and management (DQM): This benefit includes data collection, data transformation, data accessibility, and interoperability within a system of the financial institution. Financial organizations can create a smooth data flow within the system us-

ing DT. For instance, **INT02** stated: "Interoperability or Federation: this is the ability to bring different DT or extract data from different DT into a Common View". They can also better understand their systems. **INT05** commented: "It becomes important to make connections between the DT and have interoperability that then opens up the possibility of understanding systems better".

Risk Mitigation (RM): This benefit is about predicting and diagnosing potential risks, which gives financial organizations an opportunity to either avoid or reduce them. It can be achieved with the prediction capabilities of DT. For example, **INT02** gave an example: "Insuring your assets if you can reduce how much you pay on your debt insurance, that will reduce the risk on your investments".

Interviewee	DDM	DV	DQM	RM
INT01	1	0	1	0
INT02	1	2	1	1
INT03	1	1	0	1
INT04	1	1	0	1
INT05	1	1	1	0
INT06	1	0	1	0
INT07	0	0	0	1
INT08	0	1	0	1
INT09	1	0	1	0
INT10	1	0	0	1
INT11	0	0	0	0
INT12	0	1	2	0
Total	8	7	7	6

Table 4: Number of benefits mentioned by interviewees

Name	Description	Example
DDM	Financial institutions can see how things are developing in the future, and if they can judge where investment makes sense, then that can offer some support for the investments.	They have a DT model of current assets being purchased by investors. They need data like what they buy and their ESG perspective, and what sort of fee levels they are looking for. Then they use any number of machine learning algorithms and start to put those in for future days. After they get new insights, they plug that back into their model and see what the ultimate outcome will be.
DV	Visualizing data can provide better insights into the system, its processes, and its impact.	a DT tries to represent the data in the greater context of the whole system. For example, you look at GDP growth in relation to population growth to the number of companies opening and closing. And by looking at all these different factors, you get a more nuanced image that you can start to explore.
DQM	IT includes data collection, data transformation, data accessibility, and interoperability within a system of the financial institution. Financial organizations can create a smooth data flow within the system using DT.	A financial institution wants to get a new asset with a certain expected outcome, you can use DT to simulate different scenarios with a big set of data and define the best solution which will save you money.
RM	The ability to be data-driven and facts-driven to have a better understanding and assessments of risks and more accurate predictions.	Some credit agencies are essentially creating DT of people and how they act to give them better information to make decisions on whether somebody is a suitable candidate for a certain type of credit.

Table 5: Summary of Benefits

4.3 Challenges

RQ3 is about the challenges of DT usage in the financial sector. There are 6 challenges, time frames, and prerequisites for the financial sector to incorporate DT, such as "Time Frame", "Technical Aspects", "Clear Business Case", "Resources", "Social and Legal Aspects", and "Digitalization Level". The number and the kind of challenges mentioned by interviewees are represented in Table 6. The summary of challenges with description and example is shown in Table 7.

Interviewee	TF	TA	CBC	Resources	SLA	DL
INT01	1	0	0	0	0	0
INT02	3	2	1	1	0	1
INT03	2	1	0	1	0	2
INT04	2	0	1	1	1	1
INT05	1	2	1	0	1	0
INT06	1	0	0	1	0	0
INT07	3	1	1	1	1	0
INT08	0	0	1	0	1	0
INT09	0	1	1	0	0	0
INT10	1	1	1	0	0	0
INT11	0	1	0	0	1	0
INT12	2	2	0	2	1	1
Total	16	11	7	7	6	5

Table 6: Number of challenges mentioned by interviewees

Time Frame (TF) challenge refers to how soon financial institutions can start incorporating DT and how much time it is going to take. The time frames stated by interviewees differ depending on various factors such as the digitalization level of the institution, the scale of the DT, etc. Although, regardless of sector, it can take several years for major integration. A simple DT can already be implemented today. **INT02** explained: "DT is ready to be used. Implementing one use case can take three to six months. If it's transforming how an organization manages all its investments, etc, it can be one to two years". The usage of DT will become more common over time, **INT04** said: "Over the next few years, we'll see it become more normal to have DT". The time frame is also correlated with other obstacles such as digitalization level, **INT03** stated: "It depends on digitalization level".

Technical Aspects (TA) challenge is about technical obstacles for DT incorporation such as infrastructure, cyber security, etc. **INT02** gave an example regarding security

risks of data sharing: “One of the obstacles is cyber security: because if you’re hosting your data on the digital platform or sharing it between organizations within your portfolio, there is an added risk”. Another technical hurdle for financial institutions is to design a DT system that can incorporate new data sources as they come. **INT12** commented: “One of the obstacles is infrastructure: designing a modular DT that works. This is a task that I would say is very difficult for the financial sector because it’s already difficult for computer scientists”. The technical maturity of the institution is another prerequisite to incorporating DT. **INT05** stated: “It requires a great deal of new technology and new understanding”.

Clear Business Case (CBC) challenge is about having a clear purpose for DT usage along with a solid use case and connecting those two. **INT05** commented: “It’s really important to define the purpose of a DT, and the purpose is usually related to making some kind of better decision faster”.

Resources challenge refers to the sufficient number of data sources, their quality, and major investments for DT incorporation and usage. **INT04** stated: “Having data sources that are of appropriate quality and that are available and that are interoperable is one of the prerequisites”.

Social and Legal Aspects (SLA) challenge refers to legal agreements regarding data sharing as well as overcoming a public perception when it comes to personal data access and privacy, as the incorporation of DT requires modifying the legal commercial agreements. **INT05** explained: “The biggest obstacles will be human and organizational factors like modifying the legal agreements and commercial agreements”. and **INT08** highlighted: “Safely sharing the data into the DT environment is obviously a key obstacle”.

Digitalization Level (DL) challenge refers to the obstacles that emerged by governments, society, and companies. For example, digital exclusion among people creates an obstacle for DT to collect enough data about those customers. **INT12** explained: “It will require a high level of digitalization on all levels of society, of companies, of government because you need that information”.

Name	Description	Example
TF	How soon financial institutions can start incorporating DT and how much time it is going to take. It depends on various factors such as the digitalization level of the institution, the scale of the DT, etc.	Regardless of sector, it can take several years for major integration. A simple DT can already be implemented today.
TA	Technical obstacles for DT incorporation such as infrastructure, cyber security, technical maturity, etc.	Financial institutions are to design a DT system that can incorporate new data sources as they come.
CBC	Having a clear purpose for DT usage along with a solid use case and connecting those two.	Define the purpose of a DT and the purpose is usually related to making some kind of better decision faster.
Resources	Sufficient number of data sources, their quality, and major investments for DT incorporation and usage.	Having data sources that are of appropriate quality and that are available and that are interoperable.
SLA	Legal agreements regarding data sharing as well as overcoming a public perception when it comes to personal data access and privacy, as the incorporation of DT requires modifying the legal and commercial agreements.	High level of digitalization on all levels of society, of companies, of government is required because financial institutions need proper data sources to collect necessary data.
DL	Obstacles that emerged by governments, society, and companies. For example, digital exclusion among people creates an obstacle for DT to collect enough data about those customers.	People who don't have access to the internet, to smartphones, to the ability to interface with the digital world, the financial institutions need to think about how they're going to support those people.

Table 7: Summary of Challenges

5 Discussion

This section answers research questions and assembles the results of the research together in a framework which is presented in Table 9 and Table 10. The primary purpose of the framework is to summarize and categorize use cases of DT mapped with benefits and challenges. Some limitations of this study are also presented in this section.

As discussed in section 4.1, there are potential use cases of DT in the financial sector: customer service, operational efficiency, risk management, trading and investment, asset management, and compliance and regulations. All of these use cases are supported by DT's transparency, since it is critical to provide open and transparent access to information and data connected to their systems and processes. Most interviewees mentioned Customer Service use cases, this category also has the highest number of use cases such as the improved customer support use case , the enhanced customer service use case, and fraud prevention use case. The least number of mentions are about Compliance and Regulations.

As discussed in section 4.2, since DT can potentially be used in the financial services industry, there are certain benefits: data-driven decision-making (DDM), data visualization (DV), data quality and management (DQM), and risk mitigation (RM). Most interviewees mentioned data quality and management as a benefit. Four use cases like risk management, operational efficiency, compliance and regulations, and customer service enhancement can provide this benefit. Operational efficiency, trading and investment, and asset management use cases can provide data-driven decision-making benefits. Risk mitigation can be provided by use cases like risk management, asset management, and customer service, more specifically fraud prevention.

As discussed in section 4.3, there are challenges, such as prerequisites and time frames, for the financial sector to incorporate DT. Results show that those are time frame, technical aspects, clear business case, resources, social and legal aspects, and digitalization level. Most interviewees mentioned technical aspects as an obvious obstacle. The time frame of DT usage was asked in each interview and was considered a challenge according to most responses. Results show that it correlates with other challenges like digitalization level and technical aspects. All the challenges are to be faced by financial institutions regardless of the use cases; that's why they are not mapped to particular use cases.

5.1 Framework

The framework, which is presented in Table 8, represents six categories of use cases. They are categorized as internal and external use cases which the internal ones are im-

plemented within the financial institutions, whereas the external ones are manifested outside of those institutions interacting with external stakeholders such as regulators, customers, investors and traders (see Figure 8). The transparency connected to each use case is the foundation of both external and internal use cases as it refers to open and transparent access to data connected to the systems and processes of the financial institutions. The challenges identified in this study are not mapped to particular use cases, as they are common obstacles for any financial institution incorporating DT (see Figure 7).

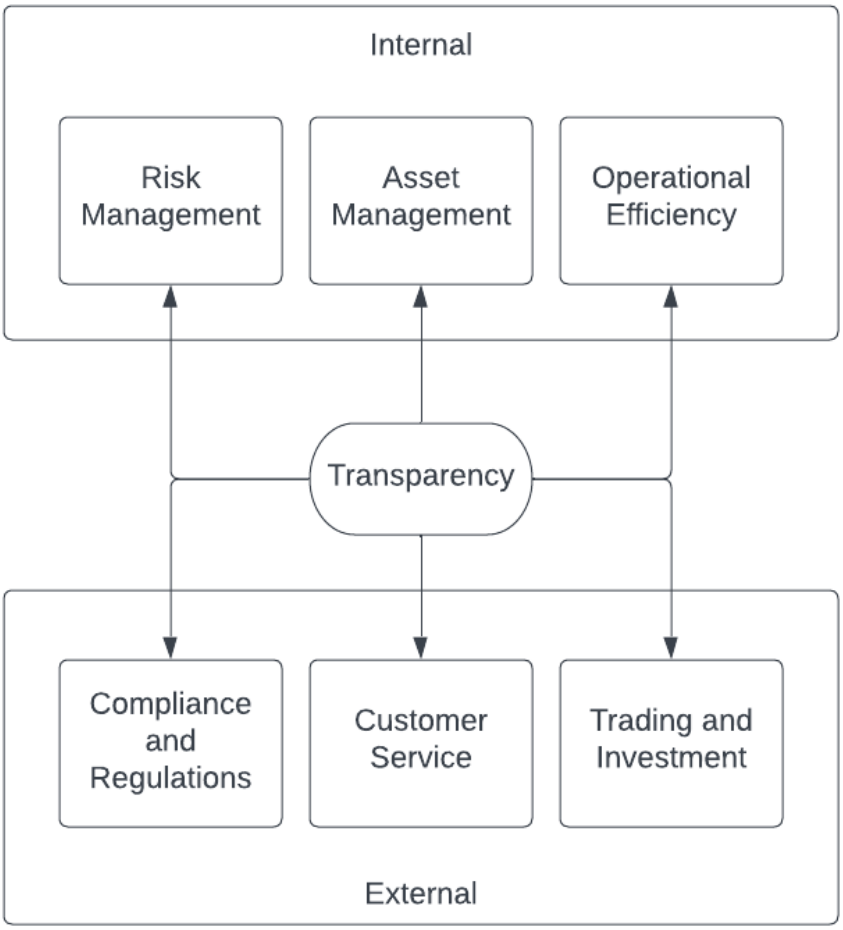

Figure 8: Overview of framework

Use case	Description	Example	Benefits
Customer Service			
Improved Customer Support	Financial institutions can have the DT of the customer journey and simulating the customer's financial circumstances and identifying the core cause of the issue.	A bank, for example, can use a customer's digital replica to detect when they are approaching their credit limit and offer them alternatives to prevent exceeding their limit or a credit line increase. This service can be provided in real-time with the help of the modeling abilities of DT.	DV
Enhanced Customer Service	A financial organization can better understand each customer's individual requirements and preferences by generating DT of their profiles and adapting products and services to those particular needs.	This organization, for instance, can build a DT of a customer journey who is a small company owner. The DT can provide insights into the customer's unique wants and preferences by evaluating data on the customer's financial transactions, business performance, etc. Based on this data, the organization can provide a credit line with flexible repayment terms with reduced interest rates.	DDM
Fraud Prevention	It refers to building a digital replica of a customer's account is one of the ways DT can be used to detect fraud. This digital replica can be used to monitor an account and its transaction history in real-time, utilizing algorithms and machine learning models to spot patterns and abnormalities that might suggest fraudulent action..	A customer's DT can show abnormal login activity like trying to access the account from an unknown device using the visualization capabilities.	RM

Use case	Description	Example	Benefits
Operational Efficiency			
Process Improvement	Financial institutions can create DT of the operational processes and use them to simulate various scenarios and identify potential bottlenecks and other areas for improvement.	A financial institution such as a bank can improve its loan approval process by creating a DT of this entire process that models everything from application to the final acceptance or rejection. Using this DT, they simulate various scenarios and test the result of changes in this process. They can extract data on loan history from DT and analyze it using machine learning algorithms to understand ways that can be used to improve this process.	DQM, RM
Resource management	It optimizes resource allocation by developing DT of the financial institution's physical assets and processes.	A bank, for example, has many branches in different regions, each with a varied degree of client activity and staffing requirements. The bank can test different situations and allocate resources more efficiently by creating DT for each branch. Having a set of connected DT of these branches provides extensive insights to help with defining what branches have increased consumer traffic and demand additional employees during peak periods.	DDM

Use case	Description	Example	Benefits
Risk Management			
Risk Analysis	A financial institution can analyze large amounts of data collected by DT to identify patterns, make predictions, and evaluate risks using data mining, machine learning, and other analytical techniques.	A financial firm might use predictive analytics to predict a loan applicant's chance of default based on a variety of criteria such as credit history, income, and work status.	DDM, RM
Predictive Analytics	DT can spot patterns and abnormalities in data using machine learning algorithms, predict possible dangers in real-time, and assist financial institutions in taking measures to mitigate those risks.	A financial firm, for instance, can create DT of a customer to simulate various scenarios, such as changes in income or important life events such as marriage or retirement, and evaluate the potential impact on the customer's capacity to repay loans or manage their financial responsibilities. This data can be utilized to inform the firm's lending and risk management decisions for that specific client.	DDM, RM
Trading and Investment			
Automated Trading	DT can be used to monitor the performance of trading algorithms and adapt them in response to changing market conditions, allowing traders to make better better decisions and optimize their profits.	Financial institution can utilize DT of the stock to model how the stock price might respond in various situations and market conditions to develop an algorithmic trading strategy for that stock. Then the algorithm can predict that the stock is likely to grow in price because of positive return outcomes, and execute a buy order accordingly.	DDM

Use case	Description	Example	Benefits
Market Analysis	Financial institutions can create virtual replicas of financial markets, which can be analyzed using advanced algorithms and machine learning techniques using DT.	A financial organization, for instance, can build DT of a specific stock market and use predictive modeling and machine learning algorithms to evaluate market trends and discover patterns that would not be clear from raw market data. This data can then be utilized to advise investing strategies and assist traders in making better decisions.	DQM
Asset Management			
Predictive Maintenance	With the help of DT financial institutions can get real-time data and insights about assets, which can help to optimize their performance, increase their lifespan, and reduce maintenance expenses.	A bank, for example, can monitor ATM machines in real-time, detecting potential problems before they happen. This can include monitoring the state of the ATM's various components, such as the cash dispenser, card reader, and network connectivity, as well as utilizing machine learning algorithms to evaluate usage patterns and discover anomalies. This bank can repair or replace it during off-peak hours by predicting when it's needed to prevent downtime and ensure customers always have access to operating ATMs.	DDM, DV

Use case	Description	Example	Benefits
Compliance and Regulations			
Regulatory Reporting	It is manifested in the financial sector via submitting required information and data to regulatory bodies and proving that the regulations are met. By providing a more accurate and effective approach to collecting and analyzing data, DT can assist financial institutions with regulatory reporting.	A financial institution can use DT of its operations to observe and track in real-time its compliance with regulations related to the General Data Protection Regulation (GDPR) and Payment Card Industry Data Security Standard (PCI DSS) requirements. DT can provide automatic data collection and aggregation from various sources within a financial institution, like customer information and financial statements.	DQM, DV

Table 8: Framework

5.2 Limitations

There were certain limitations, such as finding a person for an interview who had expertise in both DT and financial services. Eleven participants were not from the financial sector but had expertise in DT, whereas only one participant was from the financial services industry and had some knowledge about DT. Some participants struggled to talk about DT use cases in the context of the financial sector, so they were assuming things about this sector based on knowledge from other industries.

6 Conclusion

This thesis aimed to identify the use cases of DT and what benefits and challenges it could bring. This was carried out by doing background research, conducting interviews, and thematic analysis. The background research helped to shape the idea about DT and formulate interview questions. The data was collected by conducting semi-structured interviews with people who had knowledge and experience about DT. The collected data was analyzed using the thematic analysis method; as a result, six use cases were formed - Customer Service, Operational Efficiency, Risk Management, Trading and Investment, Asset Management, and Compliance and Regulations as well as their foundation - transparency. These use cases were placed into a framework and mapped with benefits that were identified during data analysis: Data-driven Decision Making, Data Visualization, Data Quality and Management and Risk Mitigation. This framework also includes descriptions and examples for each use case delivering a value to the financial institutions.

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Appendix

I. Interview Guideline

Research Questions:
RQ1. What are the potential use cases of the digital twin in the financial industry?
RQ2. What benefits can the digital twin bring to the financial industry?
RQ3. What are the challenges of incorporating the digital twin in the financial industry?

Materials, software, and environment: a printed version of this document, a printed consent form, a printed interview questions, a piece of paper, a pen, a laptop, a charger, the headphones, a glass of water, Zoom, a quiet place

Introduction: This is a study conducted by a research group from the University of Tartu (Estonia). This study is part of a Master's Thesis. The study's objectives are to research how Digital Twin can be used in the financial sector. The study aims to develop a framework for the Digital Twin in the financial sector. The framework will put into the organized system the notable use cases, capabilities, challenges, and time frames of the Digital Twin in the financial industry.

During the study, Researcher will conduct an interview with you on the topics mentioned above. The researcher will record the conversation during the study.

Overall procedure:

Before the interview:

1. Send a consent form to the participant and ask them to sign before the interview. Upon receiving: assign an index number to the file, and store it in a separate designated folder.
2. Send a Zoom link to the participant.
3. Create a Google Calendar event and invite the participant. Add a Zoom link to the event description.
4. Right before the interview: Check if all materials are there (see materials above)

During the interview:

1. Welcome the participant.
2. Thank her/him for participating in the study.
3. Introduce yourself.

4. Introduce the study (see introduction part above).
5. Ask the participant if s/he has any clarifying questions about the study.
6. Start video recording.
7. In case the participant did not send a signed consent form: walk the participant through the form and ask for verbal consent on the record.
8. Conduct the interview.
9. Ask for additions/clarifications.
10. Stop recording.
11. Thank the participant again.

After the interview:

1. Convert the video recording. Delete a video file.
2. Assign the index number to the audio file, and store it in a designated folder (not the same one that contains the consent forms).
3. Write down the initial findings of the interview.

II. Consent Form

Study title: Digital Twin in the Financial Sector
Researcher: Matin Manafov, Master's Student, University of Tartu
Supervisor: Fredrik Milani, Associate Professor of Information Systems, University of Tartu

Introduction: This is a study conducted by a research group from the University of Tartu (Estonia). This study is part of a Master's Thesis. The study's objectives are to research how Digital Twin can be used in the financial sector. The study aims to develop a framework for the Digital Twin in the financial sector. The framework will put into the organized system the notable use cases, capabilities, challenges, and time frames of the Digital Twin in the financial industry.

During the study, Researcher will conduct an interview with you on the topics mentioned above. The researcher will record the conversation during the study.

Participation requirements: To be eligible to participate, a person should 1) be 18 or older, 2) have work experience in the financial sector and/or expertise in the Digital Twin, and 3) be a fluent English speaker.

Expected duration of the study: The study will take about 45 minutes of your time.

Risks and Benefits: The risks associated with this research are no greater than those ordinarily encountered in daily life. There are no direct benefits to participants, but the development of the publicly accessible Digital Twin framework is anticipated.

Privacy and Confidentiality: In order to protect the participants' identities during this study, the research team will follow the following procedure. The original recordings will only be accessible to the Researcher and Supervisor. The audio contained in the recordings will be transcribed, potential identifiers will be removed or aggregated, and the original recordings will be deleted afterwards. Your data and consent form will be kept separate. Your consent form will be stored securely and will not be disclosed to third parties.

By participating, you understand and agree that the data and information gathered during this study may be used by the participating university for publication purposes. However, any identifiable information will not be mentioned in any such publication or dissemination of the research data and/or results. The University of Tartu requires all research records to be maintained for at least five years following the final reporting or publication of a project. Aggregated data will thus be archived by the Researcher for that timespan.

Questions about the Study: If you have any questions, comments, or concerns about the study either before, during, or after participation, please contact the Researcher (matin.manafov@ut.ee).

Voluntary Participation: Your participation in this research is voluntary. You may discontinue participation at any time during the research activity.

I am age 18 or older. I have read and understood the information above, and I want to participate in this study:
1. Yes 2. No

Participant: The above information has been explained to me, and all of my current questions have been answered. I understand that I am encouraged to ask questions and voice concerns or complaints about any aspect of this study during its course and that such future questions, concerns, or complaints will be answered either by the Researcher, by Supervisor, or by a qualified individual.

Researcher: I certify that I have explained the nature and purpose of this research study to the participant, and I have discussed the potential benefits and possible risks of study

participation. Any questions the participant had about this study have been answered, and we will always be available to address future questions, concerns, or complaints as they arise.

Participant (signature placeholder) Researcher (signature placeholder)

III. Interview Questions

Hi! Nice to meet you! How are you?
Thank you for being here and volunteering your time for the study!

As I wrote to you before I am researching the Digital Twin in The Financial Sector. To proceed with the meeting I would like to start the recording, then I am going to walk you through the Consent From, which will take 2 minutes, and ask for your verbal consent to participate in the study. Then I am going to get to the questions. Does it sound good to you? Do you have any questions for me?

1. How can digital twin technology be used in the financial sector? What value would the usage of digital twin technology bring to financial institutions and customers?
2. What would be the motivation for financial institutions to use digital twins?
3. How can digital twin technology improve the processes in financial institutions? What features of digital twin technology would be the most valuable for financial institutions?
4. What are the obstacles for financial institutions to incorporate digital twins?
5. How soon can financial institutions incorporate digital twin technology? What are the periods for the financial industry to develop and change solutions around DT?
6. What are the prerequisites for DT to enter the financial sector?

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