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Digital Twin Technology in Financial Services

Master's Thesis (30 ECTS)

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Digital Twin Technology in financial services

Abstract:

The focus of this thesis is the exploration of potential use cases of digital twins in financial services. This study explores the use cases, benefits, and challenges of the implementation to define the value and impact this technology can bring to financial services. As a result of the case study, four potential use cases of digital twins were identified, as well as four benefits and four challenges of digital twin adoption. The main contribution of this research is a framework that can help practitioners and researchers understand how digital twins can be utilized in financial companies.

Keywords: digital twin, financial sector, financial services, case study

CERCS: P170

Digitaalne kaksiktehnoloogia finantstööstusele

Lühikokkuvõte:

Selle lõputöö keskmes on digitaalsete kaksikute võimalike kasutusjuhtude uurimine finantsteenustes. Selles uuringus uuritakse juurutamise kasutusjuhtumeid, eeliseid ja väljakutseid, et määratleda väärtust ja mõju, mida see tehnoloogia võib finantsteenustele tuua. Juhtumiuuringu tulemusel tuvastati neli digitaalsete kaksikute võimalikku kasutusjuhtu ning neli eelist ja neli väljakutset digitaalse kaksiku kasutuselevõtul. Selle uurimistöö peamine panus on raamistik, mis aitab praktikutel ja teadlastel mõista, kuidas digitaalseid kaksikuid saab finantsettevõtetes kasutada.

Märksõnad: digitaalne kaksik, finantssektor, finantsteenused, case uuring

CERCS: P170

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1 Introduction

The advantages of the digital twin (DT) technology in intelligent manufacturing, medical treatment, architecture, education, and other fields are explored and show a prospect of expanding due to the development of the Internet of Things, artificial intelligence, big data, and other technologies (Xin et al., 2023). A digital twin is a software system that leverages models and data from and about an original (cyber-physical) system to represent, predict, and prescribe its behavior for a specific purpose (Andreas Wortmann, 2024). The digital twins serve different purposes, including analysis, control, and behavior prediction, and they are used at different times relative to the represented system, e.g., before it exists to explore its design space or during its runtime to optimize its behavior (Andreas Wortmann, 2024).

DT concept refers to a digital representation of a physical entity that is able to reflect its physical behavior by applying platforms and bidirectional interaction of data in real time. The deployment of the Internet of Things in the power grid has led to reliable access to information that improves its performance and equips it with a powerful tool for real-time data management and analysis (Tao et al., 2019). DTs and big data analytics are mutually reinforcing technologies on account of smart manufacturing. DTs can integrate the physical and virtual data throughout a product lifecycle, which leads to a large volume of data that can be processed by advanced analytics. Then, the results of the analysis can be used to improve the performance of a product or a process in the physical space (Qi & Tao, 2018). DTs have become a strong presence in the manufacturing industry, and they are both expanding in capability and entering other sectors. They are an important component in Digital Transformation, and they are a gateway bridging the physical and the cyberspace (Saracco, 2023).

However, there are more domains where DT technology can be applied. The increasing interest of enterprises in digitalization opens up numerous potentials for digital applications in order to increase operational productivity and efficiency. Both scholars and practitioners agree on the potential of the DT to foster digitalization across multiple industrial sectors. Therefore, the DT can enable the digital transformation of enterprises (Rabe & Kilic, 2022).

Banking and insurance are, conventionally, industries where events are systematically and securely recorded, and the underlying processes are highly structured and mostly automated. Therefore, in service industries like the financial sector, the data is already digital and can be used in various ways, including the application of DT technology.

However, applications of DTs for constant improvements in business processes in the finance and banking industry have not been studied in particular. For instance, there have been multiple publications exploring the application of the digital twin concept in medicine. DT technology in medicine has become an important development direction of intelligent medicine. The application

of digital twin technology in the field of personalized medicine and digital medical systems will promote the fundamental change of traditional electronic health and push it into a new era of personalized medicine and digital medical systems (Zhang et al., 2023).

In addition, there is a discussion on the development of an intelligent, transparent, collaborative, and resilient supply chain system to cope with unexpected supply chain disruptions (X. Lu et al., 2022). Furthermore, there are studies in the field of energy systems and smart city operation problems in severe conditions using digital twin concept technology (Q. Lu et al., 2021).

However, these studies do not consider the use of Digital Twin for the financial industry to propose business solutions that add value to businesses in this domain. The existing studies do not explore the potential application of DT technology in services where physical objects are not the actual systems to build a DT for, but an actual system is a service or a process for which the data already lives in a digital and not in the physical world. In this work, we explore and discuss potential use cases for digital twin concept applications in a payments company that provides financial services such as payments and subscription services.

Research Questions.

This study aims to explore how financial companies can benefit from DT technology. It examines what impact DT technology can possibly have on financial services. Therefore, this thesis discusses the following research questions:

RQ1: What are some potential use cases of DT for financial services?

RQ2: What benefits can DT bring to financial services?

RQ3: What are the challenges of using DT in financial services?

We address these research questions by conducting a case study. The aim of the case study is to explore potential cases of the use of digital twin technology in financial services. The company where the case study is organized is an international payments company. Due to confidentiality, the company's name is not disclosed in this paper, and the company will be referred to as FinPay here and further in the thesis.

The contribution of this thesis is exploration results that cover the application of the digital twin concept in the finance industry. Financial institutions such as banks, fintech, and micro-loan companies, as well as product managers, marketing and sales specialists, and management from such companies, can potentially benefit from the results in order to improve various performance metrics.

The structure of this thesis is as follows: in section two, we present the background and the related work; section three covers the methodology of this study. Section four presents the results of this thesis, followed by a discussion of them in section five.

2 Background and Related Work

In this section, the concept and definition of Digital Twin technology will be described. We explore its applications across various domains and present relevant use cases. Additionally, we discuss the key components and characteristics of Digital Twin technology, establishing a solid baseline for further exploration.

2.1. Digital Twin Concept

Advances in fields like the Internet of Things (IoT), Cyber-Physical Systems (CPS), Industry 4.0, Big Data analytics, and hardware (especially sensors) have enabled the application of the DT paradigm in a number of fields and for a variety of purposes. Based on a market research report, the global Digital Twin market size was valued at USD 12.91 billion in 2023. The market is projected to grow from USD 17.73 billion in 2024 to USD 259.32 billion by 2032 (Digital Twin Market Size, Share & Industry Analysis 2024 – 2032, 2024).

The Digital Twin gained traction in 2002 after Michael Grieves held a presentation at the University of Michigan, which was entitled "Conceptual Ideal for Product Lifecycle Management." The original slide containing the proposed concept was reproduced by Grieves and Vickers in (M. Grieves, 2014), and it can be noted that the early architecture of what would later become the DT consisted of three main components:

- the real space,
- the virtual space,
- the link serving as a communication medium between the two spaces.

According to (Francis Bordeleau, Benoit Combemale, Romina Eramo, Mark van den Brand, Manuel Wimmer, 2020), a DT is a virtual representation (or replica) of an Actual System (AS) that is continuously updated with real-time data throughout its life-cycle and, at the same time, can interact with and influence the AS. To clarify, the Actual System in the case of financial services is not the real or actual process but what is logged in the system. For providers of financial services, almost no data exists that is not recorded digitally in the system nowadays.

DTs can be built for a variety of purposes, such as the design, development, analysis, simulation, and operation of non-digital systems to understand, monitor, and/or optimize the AS. Many domains employ DTs to better understand, control, and optimize the behavior of complex systems, either during their design time (such as for design space exploration) or at runtime (for example, to improve performance/productivity or prevent failures). Hence, DTs are becoming an important software engineering tool to harness the complexity of software engineering in a wide range of application domains. To this effect, we consider a DT of an AS to comprise a set of models of that AS and provide a set of services that use data, possibly obtained from the AS, and models for

specific purposes with respect to the AS (Romina Eramo, Francis Bordeleau, Benoit Combemale, Mark van den Brand, & Manuel Wimmer, Andreas Wortmann, n.d.).

Despite a plethora of definitions, there is little consensus about what a digital twin is. For the purpose of current research, the following definition is used: A digital twin is a software system that leverages models and data from and about an original system to represent, predict, and prescribe its behavior for a specific purpose.

It is worth mentioning that process mining is sometimes referred to as an implementation approach for a DT for a process or an organization (Park & Van Der Aalst, 2021). However, within the context of this thesis, we understand DT as a replica that has a real-time connection to its actual system, while process mining primarily operates on logs. Unlike the process mining technique that is used primarily by business analysts, DT in finance is supposed to be used in operations by operational managers and specialists such as product managers, monitoring specialists, and engineers. In addition, process mining is often used for business process discovery, whereas for a digital twin's actual system, the process is assumed to be known. Finally, the DT in finance, within the context of this thesis, can be built not only for a process but for a product, a service, or a system.

2.2. Components and characteristics of Digital Twin

As was described earlier, a DT is a virtual representation of AS that exists within its environment. The AS produces data that is related to different aspects of the system, and the DT captures this data and uses a set of models to conduct different types of operations/actions on the AS.

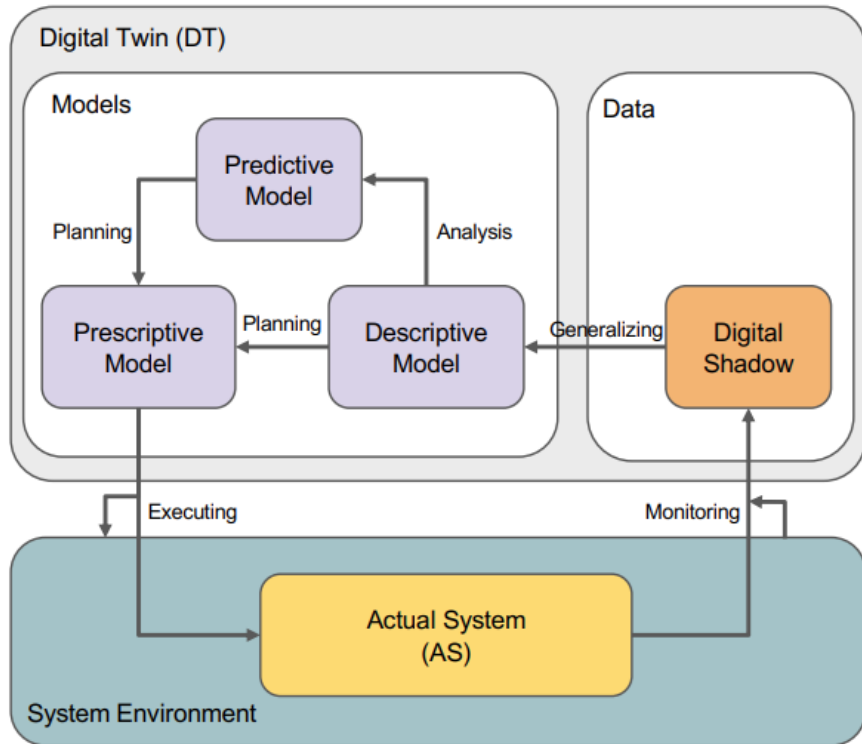


Figure 1: Conceptual framework for DTs based on MODA (Romina Eramo, Francis Bordeleau, Benoit Combemale, Mark van den Brand, & Manuel Wimmer, Andreas Wortmann, n.d.).

The main components of the framework are as follows based on (Romina Eramo, Francis Bordeleau, Benoit Combemale, Mark van den Brand, & Manuel Wimmer, Andreas Wortmann, n.d.).

- **Actual system and its environment.** The AS refers to the system associated with the DT. Collecting and storing as well as calculating and inferring data—depending on the system itself—is mandatory for a DT, which should capture the relevant aspects, including the required features and relationships, of the AS with respect to the contexts and environments (System Environment) in which it operates (Minerva et al., 2020). The AS is an essential element for the existence of the DT itself.
- **Data.** This component manages the storage and representation of relevant current and historical data for the AS in the context of the DT. Data and information are needed to represent the AS in the specific digital models of the DT. A DT comprises different types of data flows: data obtained from monitoring and sensing, measured data, and external/historical data from the system or its environment (e.g., environmental data, technical data, constraints, etc.). To this end, DTs comprise Digital Shadows, i.e.,

purposefully abstracted and aggregated data structures (P. Bibow, M. Dalibor, C. Hopmann, B. Mainz, B. Rumpe, D. Schmalzing, M. Schmitz, and A. Wortmann, 2020), that represent one-way data flow between the state of the AS and its digital representation.

- **Models.** This component is represented by one or more models of the system or its parts (W. Kritzinger, M. Karner, G. Traar, J. Henjes, and W. Sihn. D, 2018). Models address different aspects and disciplines of a system (e.g., engineering models, software models, scientific models) and can be of various language types (Francis Bordeleau, Benoit Combemale, Romina Eramo, Mark van den Brand, Manuel Wimmer, 2020). As defined in the MODA framework (Combemale et al., 2021), there are three roles that models can play in a DT: Descriptive Model, Predictive Model, and Prescriptive Model. A Descriptive Model reflects the system or the system's environment in a descriptive manner, representing current or past aspects of the actual system, facilitating understanding, and enabling analysis (Combemale et al., 2021). The arrow labeled Generalizing (between Digital Shadow and Descriptive Model) represents the application of techniques that generalize the different kinds of data to yield (or calibrate) a descriptive model. In addition, models may also reflect the actual or future system behavior in a predictive or prescriptive manner. A predictive model is used to predict information that has not been measured, allowing for decision-making and trade-off analyses. This can include models for analysis, simulation, and machine learning (e.g., different types of neural networks). In contrast, a Prescriptive Model is a description of the system to be realized, driving the constructive process, including runtime evolution in the case of self-adaptive systems (Combemale et al., 2021).

2.3. Industries where Digital Twin is used

While DT was initially intended as a tool for monitoring the lifecycle of a manufactured product, academia and the industry soon realized that the DT concept could be fruitfully applied to other economic domains as well. Today, DT is used in such industries as construction, education, energy, health, ICT, manufacturing, mining, transport, and storage (Andreas Wortmann, 2024).

With regard to manufacturing industries, the digital twin usage can be demonstrated using supply chain examples. The modern supply chain has features of low inventory volumes, just-in-time production, and accurate scheduling of transportation that make the supply chain systems vulnerable and fragile to unseen disruptions caused by political unrest, natural disasters, and financial instability (X. Lu et al., 2022). During the last two decades, numerous events and disasters, such as Hurricane Katrina in 2006, the 2008 global financial crisis, the tsunami in Japan in 2011, and 2016 BREXIT, caused a remarkable number of SC disruptions, which resulted in long delivery delays, production suspensions and decreasing revenues and sales in supply chains (X. Lu et al., 2022). DT technology allows for the optimization of supply chain management

strategies and the reduction of unwanted products, wasted places in the chain, and poor return on investment (Dombrovskiy et al., 2023).

Another example of using DT is in the health industry, where a framework for the cloud healthcare system is proposed based on digital twin healthcare (CloudDTH). This is a novel, generalized, and extensible framework in the cloud environment for monitoring, diagnosing, and predicting aspects of the health of individuals using, for example, wearable medical devices, toward the goal of personal health management, especially for the elderly. (Liu et al., 2019)

However, DT technology can also be used in service industries. For instance, the product lifecycle management process. Product lifecycle management partly includes the virtual representation of operational processes. In this context, a digital twin representing the lifecycle of a product extends its scope to the entire value chain and, thus, establishes also a link to the virtual representation of the process flow (Rabe & Kilic, 2022).

2.4 Related work

To conduct a review of the related work on the topic of digital twins in finance, a comprehensive search strategy was implemented to identify relevant articles, conference papers, and reports published in academic databases and other sources.

(Zhang et al., 2023) investigates the research status of digital twin technology in the medical field and conducts quantitative statistical analysis. The results show that the digital twin has a certain basis in medical development and can play a pivotal role in formulating highly personalized treatment plans for the future.

In (Q. Lu et al., 2021) work, a digital twin based smart city is proposed and it focuses on two applications: smart transportation and smart energy grid. Both systems are presented in a structured design manner with several components in the digital twin system, which also contains many real implementations of different scenarios.

(Korth et al., 2018) presents a system architecture that combines a real-time digital twin of logistics systems with simulation logic in a single (modularized) model. This combination not only reduces offline work creating and maintaining such a model and decision support system but also reduces runtime in this critical real-time use case. The approach is demonstrated in two industrial use cases.

In (Stojanovic & Milenovic, 2018), a novel approach for process improvement based on data-driven modeling is presented. The idea is that by performing Big data analytics on the past process data, a model on what is (statistically analyzed) usual/normal for a selected period can be built to check the variations from that model in real-time (as Six Sigma requires) (Stojanovic & Milenovic,

2018). Additionally, these data-driven models can support the root-cause analysis that should provide insights into what can be eliminated as a waste in the process (as Lean requires) (Stojanovic & Milenovic, 2018). In order to realize this idea, authors developed a new concept of self-aware digital twins, which are able to reason about their own behavior and react if needed. The concept of digital twins is extended in this work by changing "virtual replica" (of physical objects) nature into "digital self-awareness" of physical objects (assets, systems), leading to the new generation of digital twins, so-called self-aware DTs, which can reason about the behavior of an object (and not only mimic it) and actively participate in its improvement (Stojanovic & Milenovic, 2018). This work presents the outcomes from the case study related to the 3D laser cutting process.

The above-mentioned publications mainly considered DT applications in various production industries. However, the focus of current work is on financial services. Therefore, this thesis will explore the use cases of this technology in financial services.

3 Methodology

In this section, we introduce the case study methodology and discuss its relevance for addressing our research questions. Case study research is one of the often used qualitative research methods in the field of informatics, and this method is used to develop our understanding of technology-related inventions and other developments (Darke et al., 1998). Case studies offer an in-depth exploration of specific real-world contexts, allowing us to analyze complex phenomena within their natural settings.

Our choice of case study methodology stems from its ability to provide rich, context-dependent data and facilitate exploration processes. Through a detailed examination of a financial company, FinPay's potential implementation of DT technology, we aim to uncover use cases, benefits, and challenges, contributing to a comprehensive understanding of DT utilization in financial services. Extensive literature discusses the case study method, primarily focusing on explicit guidelines for applying it within specific domains. These guidelines outline general steps for implementing case studies to address specific problems. Different types of case studies can be chosen, such as explanatory, descriptive (Hollweck, 2015), intrinsic (Stake, 1995), and other case studies.

We address this research objective by conducting an exploratory case study. This methodology suits the aim of achieving our research objective as it allows us to explore deeply specific instances of DT implementation use cases within a specific financial company. By examining real-world context, interactions, and challenges, we can uncover valuable insights, patterns, and practical implications. Through this case study, we aim to contribute to the broader understanding of digital twin adoption in the finance sector.

The research strategy was planned and designed to address the research objective. The initial step involved gathering background information on the services and products that FinPay provides for its customers, as well as the internal tools that support business operations. Subsequently, specific research questions were formulated. Semi-structured interviews were conducted to collect relevant data, posing open-ended questions to professionals working at FinPay.



Figure 2: Research stages overview

3.1. Research Questions

The research questions will address the exploration and discussion of use cases. The research questions will include the following:

RQ1: What are some potential use cases of DT for financial services?

RQ2: What benefits can DT bring to financial services?

RQ3: What are the challenges of using DT in financial services?

RQ1 explores how DT can be used in the financial industry in the context of FinPay services. The aim of RQ2 is to research the potential benefit of using DT in financial services. The goal of RQ3 is to define possible obstacles a financial company may face implementing DT in its services and products.

3.2 Case Selection

In order to answer the RQs defined in this study, we need a case that fulfills several criteria. First, the case should be within a real context of the financial industry in order to explore opportunities for digital twin incorporation in a real-world business company. Secondly, the case should deal with one or more financial products or services that have all or most of the data presented digitally. Thirdly, the case should grant me access as a researcher to explore internal company data. The case for this study takes place at the company FinPay, which is an international payments company that provides financial services such as payments and subscription payment integrations. This company has both internal and external tools and platforms to ensure smooth operation and that all the data related to the processes, services, and products is digital.

Therefore, the case is suitable for the outlined criteria as FinPay company meets the criteria of being a company in the real context of the financial industry; it also meets the criteria of having the data written into digital systems as well as it meets the criteria of granting access to their data for the current research.

3.3. Data Collection

3.3.1 Internal Documents Research

In this step, I was granted access to internal documents of FinPay, including descriptions of services, products, and internal tooling that the company uses. Additionally, we explored the public information available about the company, including its website and financial results. The purpose of this background research is to gain comprehensive insights into FinPay's main business streams, goals, products, and tools. Around 20 different documents with a total volume of nearly 100 pages were reviewed.

After an initial review of the documents, we assembled the notes, which contain all the critical information about essential products, services, and tools the company uses for further usage in the data analysis stage.

3.3.2 Interviews

The interviewees will be engaged in discussions regarding their understanding of the DT technology in services, potential use cases where digital twin technology could offer solutions as well as challenges related to DT implementation. Participants will be prompted to share their current approaches to addressing existing challenges as well as existing methodologies and any encountered limitations.

Semi-structured interviews will be conducted in order to gather the data through open-ended questions from individuals working in the company where this case study is conducted. This methodology will allow us to foster insights and gain an in-depth understanding of potential use cases, benefits, and challenges of DT implementation in financial services.



Figure 3: Data collection stage overview

Interview questions (IQs) are formed based on the research questions. The purpose of IQ1 and IQ2 is to explore possible applications of DT technology in financial services. IQ1 and IQ2 are derived from RQ1. IQ3 and IQ5 explore the benefits DT technology can bring and are based on RQ2. IQ4 and IQ6, which aim to determine technologies and challenges for DT incorporation in financial services, are based on RQ3. The interview questions can be found in Appendix III.

IQ1: What is your understanding of DT in services?

IQ2: What use cases do you see for DT technology for providers of financial services?

IQ3: What is the value of having DT, and who will benefit from it?

IQ4: What technologies can be used to enable the usage of DT?

IQ5: What impact would DT usage have on the business?

IQ6: What are the potential challenges of the implementation of DT technology in financial services?

The interviewees are FinPay employees who have experience working for this financial company. The data collection stage includes conducting seven interviews with

- Product managers
- Technical Program Managers
- Product directors

from the target company across different countries.

The list of interviewees, with their respective positions in the company, as well as the product they work on, is presented in Table 1.

ID	Position in the company	Product/Service domain
INT01	Product Manager	Payments (external service)
INT02	Product Manager	Data (internal service)
INT03	Business Analyst/Business Development	Payments (external service)
INT04	Director of Product	Payments (external service)
INT05	Technical Program Manager	Subscriptions (external service)
INT06	Product Manager	Monitoring (internal service)
INT07	Product Manager	Subscriptions (external service)

Table 1: Interviewees list

An interview guideline is presented in Appendix I and is developed to guide and structure the interview process. It consists of the following parts:

- 1) welcome the expert and introduce the research topic
- 2) request verbal consent and start the recording
- 3) ask interview questions
- 4) ask clarifying questions, if any
- 5) stop the recording and finalize the interview.

All interviews are conducted online via Microsoft Teams; the recordings are made to enable the reliability of the interview data. Interviewees must give verbal consent for recording the interview during an interview, which is requested using a consent form, which is presented in Appendix II. The interviews take from 30 to 40 minutes and follow an interview guideline. All video recordings are transcribed for further processing and analysis, followed by the deletion of the recordings.

3.4. Data analysis

The data analysis activity will be conducted by analyzing the interview data, interpreting the information, extracting keywords along with essential quotes, and comparing the data with the documents and notes from the internal documents research stage.

The interview data is analyzed using the thematic analysis approach, which is a flexible method of qualitative analysis that allows for the gaining of insights and concepts derived from data (Alhojailan, Mohammed Ibrahim and Mohammed Ibrahim, 2012). The overview of the data analysis is presented in Figure 4.

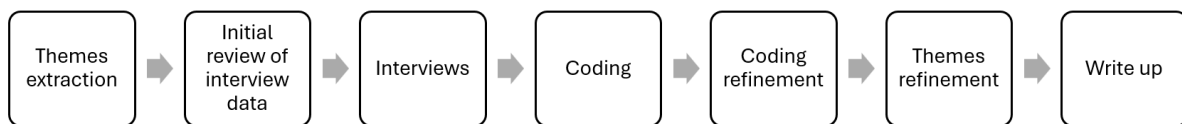


Figure 4: Data analysis stage overview

First, we generate themes based on the research questions. Each research question contributes one or two themes. For example, RQ1 raises the theme “Use case,” while RQ2 leads to the theme “Benefits.” The subsequent step involves familiarizing ourselves with the data. A comprehensive overview of all collected data is crucial before moving into individual item analysis. In this study, we reviewed a total of seven transcripts.

The subsequent step involves data coding, where we identify sections within transcripts, typically phrases or sentences. We assign shorthand labels (referred to as codes) to encapsulate their content. Afterward, we review all the codes and define patterns among them. For instance, potential use cases of DT, such as risk mitigation, marketing, and business intelligence, were frequently

mentioned in some interviews, indicating that these should be coded. The next step is to review and refine the codes to identify overlaps or redundancies. During this process, sub-codes may occur. For example, marketing-related use cases can be categorized into three sub-codes: 'Playground environment for customers,' 'Personalized products and services,' and 'Customer Retention.'

When reviewing themes, we refine codes to identify overlaps or redundancies. Multiple codes may be combined into a single theme. Defining and naming codes involves precisely formulating their meanings and understanding how they contribute to data comprehension.

For instance, naming codes include creating concise, easily understandable labels. Consider the theme 'Use Cases,' which contains four codes: 'Risk Mitigation,' 'Marketing,' 'Business Intelligence,' and 'Monitoring.' These names clearly represent the data extracted from transcripts related to use cases.

Ultimately, the last phase will include documenting the data analysis, with the conclusion on key findings and a demonstration of how the analysis addresses the research questions.

We refined and enhanced the text using tools like Grammarly and AI-based text generation, specifically Copilot. In the final step, we summarized our data analysis, highlighting key findings and demonstrating how our research questions were addressed.

4 Results

This section presents the study's findings, which include the use cases of DT in financial services, the potential benefits resulting from DT adoption, and the challenges that can potentially be faced by financial companies incorporating DT.

4.1. Use cases

RQ1 aims to explore the use cases of DT in financial services. Four potential use cases were found, namely "Risk Management", "Business Intelligence", "Marketing", and "Monitoring". Some of the use cases have sub-cases that apply to a certain area of business.

The summary of use cases with descriptions and examples is shown in Table 2.

4.1.1 Risk management (RM)

Experts mentioned that DT technology could be used for risk analysis of the customers, the market, the portfolio, and the revenue, as well as for user scoring, and it could help build future scenarios and expectations. There were more cases listed under Risk Management by the experts than are presented below. However, we will focus on some of them. In addition to risk analysis, it was noted that such procedures as underwriting and automated scoring can be improved using DT technology. Furthermore, in experts' opinion, DT technology could be used for fraud detection and prevention by analyzing previous fraud cases and building models to detect suspicious activities or transactions in real time.

This use case can be considered as an "umbrella" term for several sub-cases, the main two of which would be User Scoring and Fraud detection and Money laundering prevention.

User Scoring.

DT technology in user scoring within financial companies emerges from the interviews. This use case considers a scenario where underwriting processes are seamlessly integrated with DT and use an automated scoring system in which DT models continuously monitor customer behavior, financial transactions, and credit history. By analyzing this data, they generate real-time credit scores. These automated scores provide a holistic view of an individual's creditworthiness, incorporating both traditional credit bureau data and alternative sources. This can not only give reliable credit score information but also construct personalized loan offers. When a customer applies for a loan, the DT instantly assesses their risk profile. It considers factors such as income, spending patterns, and repayment history. Based on this analysis, personalized loan offers are generated. These offers align with the customer's financial situation, ensuring optimal terms and interest rates. As **INT01** mentioned: *"Let's say a user applied for a 10,000 euro loan with a specific*

rate, probably after scoring, it can be a much bigger deal, and we can offer, for instance, 15, 000 and with the better percentage because it's more a customer with a good score”.

Fraud detection and Money laundering prevention.

DT can help payment companies to monitor customer behavior and detect anomalies or suspicious transactions. DT technology could be used for money laundering prevention by analyzing previous money laundering cases and building models to detect and stop illegal money movements in real-time.

Interviewees noted that current AML (Anti Money Laundering) solutions use data retrospectively and are not always proactive in terms of money laundering prevention. DT presents an opportunity to reflect data on payments in real-time, thus enabling a more proactive approach to risk mitigation. As **INT06** puts it, *“Obviously, with DT, all the AML analysts would have more real-time information and tools to build and learn from it.”*

4.1.2 Business intelligence (BI)

DT technology could be used for business intelligence by analyzing the data and the market trends and providing insights and recommendations for business growth and development. The presumption is that DT can advance data usage by having replica instances or models that can change the behavior based on different inputs. In the case of payment services, the input can include

- number of customers
- revenue
- currency exchange rates
- fees

It was suggested that DT could be applied to financial services by creating models of customer data or market data and simulating different changes or scenarios to evaluate their impact on the service or the business. As **INT01** mentions, *“We need good data models with a future scenarios simulation for understanding the market.”*

Some experts proposed creating a holistic digital twin that mirrors an entire company or organization. By doing so, companies can simulate and explore various scenarios, especially those influenced by external factors like market dynamics, currency exchange rates, and interest rate fluctuations. A digital replica of the entire company that captures its processes, interactions, and dependencies can allow decision-makers to run simulations and analyze how different market conditions impact the organization. Companies can use digital twins to test strategic decisions. For example, if the company plans to expand into a new market, the digital twin can simulate the impact of currency fluctuations on revenue, supply chain costs, and profitability. This informs better decision-making. Furthermore, companies can assess their resilience by subjecting the digital twin to stress tests. Such an assessment could predict as well as prescribe how a company can deal with economic downturns, currency volatility, or interest rate changes.

4.1.3 Marketing (MA)

Playground environment for customers.

DT can be built for a whole payments system to enable potential and current clients that provide payment solutions to merchants to test the flow and see how the solution will work in real life, but in a playground or "sandbox" environment without real traffic to avoid impact on real customers. This use case for DT is in simulating the user journey for merchants integrating with financial services, allowing them to test configurations and user experiences. Interviewees consider the integration of digital twin concepts into merchant test environments, where simulated behaviors allow merchants to test API integrations, suggesting that digital twin technology could enhance the simulation capabilities for better testing outcomes.

Based on INT06 input, *“Providing this digital twin environment for our merchants to try out how the entire flow, entire user journey would look like if they integrated with us, what methods they could offer to their merchants and to their customers, and to show this exactly reproduced.”*

Merchants can use DT to simulate and assess how their services would perform in different scenarios. For example, they can test payment processing, fraud detection, or user interactions within a controlled environment.

DT can potentially allow merchants to run complex “what-if” scenarios. They can explore how changes in their services (such as introducing new features, scaling up, or adapting to regulatory changes) impact performance. This predictive capability helps them make informed decisions before implementing changes in the real world.

The envisioned benefit of DT lies in its risk-free nature. Merchants can experiment, iterate, and fine-tune their solutions without affecting actual users or transactions. Whether it's optimizing user experience, enhancing security protocols, or refining payment workflows, digital twins provide a safe space for innovation.

In the field of payment systems, the process of testing and presenting solutions to potential partners and clients has serious limitations. Traditional approaches often rely on static prototypes, mockups, or other non-interactive designs. These artifacts, while useful for conveying high-level concepts, fall short when it comes to providing an authentic experience. Experts explained that a prospective client usually interacts with an unresponsive mockup that lacks the dynamism and realism necessary to truly evaluate the system. A DT, in this context, represents a virtual counterpart of the actual payment system. It goes beyond mere visual representations by encapsulating the system's behavior, functionality, and intricacies. Unlike static prototypes, digital twins of payment systems can be dynamic and interactive. They can simulate real-world scenarios, allowing potential clients to explore the system as if it were live. Buttons can be clicked, transactions initiated, and responses observed. For example, a digital twin can replicate the payment system so the partners can test its responsiveness, error handling, and transaction flow. As a result, clients

can feel more assured that what they see in the twin reflects reality. This level of realism can potentially foster stronger confidence and trust from the partners.

Personalized products or services and Customer Retention.

It was proposed by the experts that DT and its models can enable loan or insurance companies to offer more personalized and dynamic pricing based on customer risk profile, health status, or market conditions, but also recognized that some data may be unreliable or inaccurate and that some customers may not consent to share their data.

By creating digital twins of individual customers, businesses can develop a deeper understanding of their preferences, behaviors, and needs. A DT can capture a holistic view of each customer, integrating data from various touch points such as online interactions, purchase history, social media activity, and more. This comprehensive profile enables marketers to tailor messages, offers, and recommendations based on individual preferences. As customers interact with products or services, the DT can learn about their behavior patterns, such as the products they browse, how often they engage, and when they make purchases. Marketers can leverage these insights to create targeted campaigns like personalized emails, product recommendations, or social media ads.

Experts mentioned that real-time data can help financial companies to provide better recommendations, suggestions, or incentives to their customers based on their spending patterns, preferences, or needs, but also admitted that some data may be irrelevant or outdated and that some customers may not trust or value the data-driven offers.

4.1.4 Monitoring (MO)

Maintenance of engineering systems in finance.

Interviewees emphasized the crucial role of real-time data in payments, explaining that data delayed by 24 hours is considered postmortem and useless for addressing issues like payment spikes or outages that could have significant financial impacts. That is the reason why among suggested use cases for digital twin technology in financial services, the following were proposed in order to effectively maintain engineering systems:

- modeling maximum load capacity
- handling certificate expirations
- testing disaster scenarios without impacting production environments.

Experts concluded that focusing on infrastructure analysis, such as load capacity and risk management, can prevent outages and optimize system performance. They suggested that digital twin technology could be used to test various scenarios, like certificate expirations and load handling, without the need for real-world trials, thereby avoiding potential disruptions. They also envisioned using digital twin technology to model disaster scenarios, such as data center outages,

to prepare and mitigate risks without actual system impact. **INT03** proposed several what-if scenarios, such as, "*What is the maximum TPS (Transactions per second - author's note) we are capable of managing? Under which circumstances? What is going to happen if, for example, there is a certificate expiring?*"

It is worth mentioning that some experts, although acknowledging the hypothetical nature of DT technology in finance, also highlighted its potential for efficiency and simulation in the sector. Some compared it to the disruptive nature of blockchain technology. Interviewees see the value in programming digital twins to run simulations for efficiency improvements in financial services, aligning with the concept of enhancing sector performance through technological advancements. The discussion revolved around shifting from a reactive to a proactive approach in detecting issues, with digital twin technology potentially playing a role in enhancing early detection capabilities within the payment processing ecosystem.

Use case ID	Use case name	Sub cases	Example
RM	Risk Management	User credit scoring	DT has the potential to revolutionize risk analysis in payments and loans, especially when it comes to user scoring. DT credit scoring tool could capture an individual's creditworthiness and uncover patterns and correlations, providing financial institutions with a more holistic picture of an individual's financial health and creditworthiness. DT could also constantly reflect the user's behavior, thus allowing DT to adapt to changing market conditions and ensuring that credit scoring remains relevant over time.
		Fraud detection and Money laundering prevention	DT could represent comprehensive profiles for each payment user by capturing their spending patterns, transaction history, and behavioral data. These profiles could serve as references for analyzing real-time transactions and detecting anomalies. By continuously monitoring and representing real-time transactions against these profiles, financial institutions can flag deviations that may indicate fraudulent activity and potential money laundering activities. The system can

			potentially evaluate the risk associated with each transaction by comparing it to the user's historical behavior and current activity.
BI	Business Intelligence	N/A	Digital twins provide real-time insights into financial operations. By analyzing data and key performance indicators (KPIs), financial institutions can optimize resource allocation, improve processes, and enable autonomous finance. This is crucial in today's data-driven landscape.
MA	Marketing	Playground environment for customers	A DT can act as a clone of a production environment, system, or product/service. It can precisely model the behavior and qualities of the underlying system. For merchants, this means creating a virtual representation of their services, products, or payment systems and the ability to test out different flows and scenarios.
		Personalized products or services and Customer retention	A DT can become a tool for creating more personalized offers and services by analyzing user data and payment patterns. Marketers can create virtual replicas of individual customers using historical and real-time data. Unlike static profiles, DTs can continuously update with real-life information, reflecting an individual's current state of mind and behavior. These replicas can simulate customer interactions and provide context for future marketing efforts.
MO	Monitoring	Maintenance of engineering systems in finance	DTs can potentially allow engineers to simulate "what-if" scenarios. By modeling different conditions, they assess system responses and vulnerabilities. This informs decision-making, risk mitigation, and system optimization.

Table 2: Use cases with examples

4.2. Benefits

RQ2 covers the benefits of DT usage in financial services. During the case study, four major benefits of implementing digital twin technology in a financial company came to light, including "Risk Mitigation", "Enhanced Decision Making", "Improved Customer Retention", and "Reliable Infrastructure". The summary of benefits with descriptions and examples is shown in Table 3.

Risk Mitigation (RM)

By continuously monitoring financial processes, transactions, and market conditions and analyzing real-time data, DTs can predict potential risks and vulnerabilities. Financial companies can take timely preventive actions, minimizing losses and ensuring stability. In order to mitigate fraud risks, DTs can create virtual customer profiles and replicas of financial systems and track deviations from established patterns, identifying anomalies that may indicate fraudulent activity, which enhances fraud detection accuracy. In summary, DTs empower financial institutions to make informed decisions, prevent fraud, and manage risks more effectively, ultimately improving security measures. **INT02** added: *“Obviously, fraud and AML analysts would love to have more real-time information and tools to build and learn from it.”*

Enhanced Decision Making (EDM)

DT technology has the potential to enhance decision-making within financial services by providing opportunities for proactive decision-making, scenario exploration, and data-driven insights. DTs can assist in implementing "what-if" scenarios by simulating various conditions such as economic fluctuations, customer behavior changes, or investment strategies. This simulation can effectively inform strategic decision-making in financial companies, amplifying data-driven approaches. **INT05** made an example: *“The sandbox environment, which is the replica of the production - in this case, it's gonna be useful for a lot of people. One is the actual developers trying to make the products suitable for the user. Then the other people will be the Product, the person that is actually leading the product to be sure that the initial goal of what is being developed is being met”*.

Improved Customer Retention (ICR)

By modeling different business scenarios, organizations can proactively assess risks, refine strategies, and make informed decisions, which can lead to more refined user flows as well as personalized customer experiences. By incorporating DT technology, companies can gain insights into individual customer behavior, preferences, and needs. This enables them to customize services, offer relevant product recommendations, and create personalized customer journeys. As a result, customer satisfaction increases, leading to improved retention rates. **INT03** commented: *“If we're talking from the company perspective, we explore better pricing opportunities, it means you can sell more and then maybe potentially upsell more.”*

Reliable Infrastructure (RI)

DT technology can offer a benefit in terms of improving infrastructure reliability within financial services. By simulating engineering infrastructure and disaster scenarios using DT, financial companies can run predictive risk assessments and improve real-time monitoring and scenario testing for resilience. This proactive approach enables organizations to develop robust infrastructure for resilience and adaptability. **INT03** added: *“Product and engineering teams would particularly benefit from digital twin technology, as it aligns with their responsibilities for maintaining SLAs.”*

Benefit ID	Benefit	Example	Use case name	Who benefits the most
RM	Risk mitigation	Proactive risk assessment and enhanced fraud detection enabled by DT can empower financial companies to manage risks more effectively and enhance security measures.	RM	Product, Sales, Marketing, and Risk Management, Fraud teams
EDM	Enhanced decision making	DT can enhance business intelligence, enabling companies to make proactive, data-driven decisions and explore “what-if” scenarios effectively.	BI	Product, Sales, and Marketing teams
ICR	Improved Customer Retention	Through DT, companies gain insights into individual customer behavior, preferences, and needs, which can allow them to tailor services, recommend relevant products, and create a more personalized journey for each customer. This can boost customer satisfaction and lead to	MA	Product, Sales, and Marketing teams

		improved retention rates.		
RI	Reliable infrastructure	By simulating engineering infrastructure and disaster scenarios with DT, the reliability of financial services infrastructure can be enhanced. Establishing virtual models of infrastructure and simulating disaster scenarios can help to predict potential risks and assess their impact to develop robust emergency response plans.	MO	Engineering, Monitoring

Table 3: Benefits

4.3. Challenges

RQ3 covers the challenges of DT usage in financial services. There are four main challenges in implementing DT, such as "Data Privacy, Security, and Regulation", "Cost of development and maintenance", "Relevance", and "Reliability". The summary of challenges with descriptions and examples is shown in Table 4.

Data Privacy, Security, and Regulation.

Some of the experts' concerns were related to data security and regulation issues that might arise from using digital twin technology, especially for sensitive financial data and third-party services. It was acknowledged that DT in financial services faces some challenges, such as the availability and confidentiality of data and the regulation and compliance of data usage.

Also, some data, such as personally identifiable information (PII), is not accessible or shared by the service providers or the customers due to privacy or security reasons, legal and regulatory constraints, such as GDPR, that limit the use of such data in financial transactions and analysis.

Another concern is about the cost and maintenance of developing digital twins, as well as the philosophical challenge of a digital twin not fully replicating the original object or experience. This underscores the practical and conceptual challenges in implementing digital twin technology in the finance sector. **INT04** had an example: *“Legal regulations are different. Some payment method types might require the first name, last name, and Social Security of a user. A majority of the time, you're not going to require API to do payment transactions, which is a good thing, especially the payment transactions that are noncard payments.*

When we go into the bank-based payments, some of these schemes do require some of that, so we have to be mindful of what kind of data we need to collect”.

Cost of development and maintenance.

Some experts express concerns about the high costs and maintenance efforts required to develop and sustain digital twins, especially for smaller companies.

As **INT06** puts it: *“The cost of developing a digital twin and maintaining it seems for me a bit too much for a company like FinPay that has in some way limited resources.”*

Relevance

Some experts questioned the value and feasibility of DT in finance, saying that it might not be something that companies would want to spend money on and that it might not be very different from existing solutions. As **INT01** commented in the context of Business Intelligence solutions: *“Pretty much each company already has all of that (BI - author’s note) in place.”*

Reliability

As regards the reliability of the data and insight DT provides, some experts raised a concern about DT technology not being able to fully replicate the original experience, which may limit their

effectiveness in decision-making processes, considering the resource constraints and the need for a realistic representation of services. As **INT07** commented: *“Making sure DT replicates everything that is needed is the biggest challenge, probably.”*

Challenge	Example
Data Security, Regulation Privacy, and	Not all data, especially personally identifiable information (PII), is readily available for analysis. Financial institutions handle sensitive customer data, including names, addresses, social security numbers, and financial histories. Striking a balance between leveraging data for operational insights while safeguarding privacy and complying with regulations poses a complex dilemma.
Cost of development and maintenance	Building a robust digital twin infrastructure involves substantial investment in terms of software development, hardware, data integration, and skilled personnel. Additionally, ongoing maintenance, updates, and synchronization require continuous resources. Balancing the benefits of digital twins with the associated expenses becomes crucial for financial institutions aiming to optimize their operations while managing costs effectively.
Relevance	The experts question whether implementing a DT to simulate market scenarios and optimize asset allocation is truly beneficial or merely redundant compared to traditional risk models.
Reliability	The experts are not confident that the DT can accurately capture every nuance of the complex processes, including subtle variations that affect efficiency. Ensuring that the DT accurately replicates all critical aspects can be a significant challenge, according to them.

Table 4: Challenges

5 Discussion

As described in section 4.1, four use cases of implementing DT technology in financial services were defined - "Risk Management", "Business Intelligence", "Marketing", and "Monitoring". In section 4.2, we explored the benefits that were identified during the case study: "Risk Mitigation", "Enhanced Decision Making", "Improved Customer Retention", and "Reliable Infrastructure". Finally, the case study results included an exploration of possible challenges of DT technology incorporation in financial services in section 4.3. As a result, the following challenges were discovered: "Data Privacy, Security, and Regulation", "Cost of development and maintenance", "Relevance", and "Reliability". In this part of the thesis, we are discussing the results and compare it to findings in other studies.

5.1 Results discussion

In section 4.1, we identified four use cases for implementing DT technology in financial services: "Risk Management", "Business Intelligence", "Marketing", and "Monitoring". Digital twins offer significant potential for risk management within financial institutions. We described earlier that two main applications are User Scoring and Fraud detection and Money laundering prevention. Business intelligence derived from DTs enables data-driven decisions, process optimization, and resource allocation. DTs can potentially enable financial organizations with real-time insights. Marketing use case implies a potential to create Playground environment for customers and Personalized products or services and Customer retention. Playground environment for customers will replicate the production environment for reliable testing and demos, while Personalized products or services can be created via DT real-time insights and drive Customer retention. Monitoring in financial companies can use DT technology to create tools for maintenance of engineering systems and enable simulations for better systems resilience testing and improvement.

The application of DT in financial services is not well explored yet, however, some researchers put forward the idea of applying DT technology to the field of fund management, which can be compared to the idea of incorporating DT in financial services. The digital twin modeling system is used to input the financing scheme information, collect the project data of the enterprise's preparatory consumption of the raised funds, analyze the adaptability of the financing scheme with the help of the model simulation and operation prediction function, and iteratively optimize the scheme to achieve the optimization (Wang et al., 2022). To some extent these findings can be supported with the findings of this study as we discussed that simulation and prediction are the key features of DT technology that can bring benefits to financial companies. By simulating various scenarios, DTs can predict market fluctuations and credit risks. For instance, a bank could create a digital twin of its loan portfolio, assessing the impact of changing interest rates or

economic downturns. The ability to model risk exposure and stress-test portfolios enhances decision-making and regulatory compliance. By creating a digital twin of their operations, such as customer interactions, transaction processing, and backend systems, companies gain a holistic view. For example, a retail bank could use a DT to analyze branch performance, identifying bottlenecks or underutilized resources. By modeling individual customer journeys, DTs reveal touchpoints, preferences, and pain points.

It is important to note that many issues mentioned in use cases can also be dealt with by utilizing technologies other than DT. In fact, there are many solutions for fraud detection that focus on fraud aspects using data analysis and advanced machine learning. There are some potential benefits that DT can add to a single focused fraud detection system that other technology cannot do. DT can not only reflect the real state of the system but also impact it. For example, in fraud prevention cases, DT could detect an issue, as data analysis and ML models can also do, prescribe several options for issue resolution, run a simulation based on the suggested options, compare the results, and even apply the solution by itself. The possible reason why experts in this study did not mention this advantage can be related to a lack of understanding of how DT works and what benefits it provides.

In section 4.2, we identified four benefits of implementing DT technology in financial services: "Risk Mitigation", "Enhanced Decision Making", "Improved Customer Retention", and "Reliable Infrastructure". Marketing teams can leverage DTs to meet their goals to personalize customer experiences or improve the customer journey. DT technology can leverage the maintenance of engineering systems within the financial sector by enabling real-time monitoring and playground environments.

Some studies suggest that DT technology can help companies to choose appropriate financing opportunities and plan ahead to avoid such issues as capital shortage, funds collection, rupture of enterprise capital chain and interruptions to the normal production and operations. In addition, the DT can provide decision-making reference for enterprises to raise funds reasonably, avoid excessive financing, produce a large number of financing costs and idle funds, and affect the operating efficiency of enterprises (Wang et al., 2022). These findings are in line with some potential benefits we discovered in our research such as "Risk Mitigation", "Enhanced Decision Making", "Improved Customer Retention". Another studies explore the benefits of applying DT in manufacturing and highlight the "Reliable Infrastructure" that we discussed earlier. By utilizing the power of the Digital Twin, manufacturing companies can move from being reactive to predictive. They can predict when equipment is wearing down or needs repair, improve the machine's performance, extend their lives and learn how to redesign to do even more (Attaran & Celik, 2023). Summarizing the benefits, we can describe them considering three advantages that DT provide:

- **Contextualized insights.** Digital twins contextualize data by linking it to specific business processes, assets, or customer interactions. Rather than describing isolated metrics, organizations can explore data within the broader operational context. For instance, a DT for fraud prevention can apply restrictions such as payment or transfer limitations or blocking not only based on a specific customer's behavior but also based on other ever-changing data such as market fluctuations, dynamically responding to changes and providing holistic insights.
- **Adaptive decision support.** Many modern technologies that provide prediction functionality for better decision-making, rely on historical data and predefined models, reports, and dashboards. DTs can adapt to changing conditions: if the dynamics in any component of the whole system shift, the DT can recalibrate its insights. DT can also impact the behavior of the actual system, not only describing and prescribing actions, but also applying measures and actions in the system. For instance, a financial institution's DT adjusts credit risk assessments based on real-time economic indicators. As customers engage with various touchpoints (website, mobile app, call center), the twin can adapt its recommendations. If a customer abandons an online loan application, the twin triggers personalized follow-up messages or suggests alternative channels for completion. This adaptability can improve customer experience and increase conversion rates.
- **Scenario testing.** Organizations can use DTs to simulate “what-if” scenarios which is a specificity of this technology. While many tools can run calculations and forecasts, DT can reflect the system’s whole state in case any change happens in the system’s components. For example, DT can help to answer a question like “What if the interest rate increases abruptly?” or “What if customer preferences change suddenly?”. By running simulations within the twin, decision-makers can gain more clarity on business strategy and can get more holistic recommendations. In the payments sector, DT models can potentially simulate load fluctuations, platform component failures, and extreme traffic events. By running these scenarios, engineers can assess platform resilience and plan maintenance. If the twin predicts platform overload during a traffic change, maintenance can be proactively planned, and corresponding changes can be made, preventing outages.

As discussed earlier, DTs facilitate proactive risk mitigation. By simulating various events, financial institutions can prepare remediation plans. For instance, a DT modeling a trading platform could simulate a flash crash, allowing traders to practice response strategies. Additionally, DTs aid compliance by ensuring adherence to regulations, automating audit trails, and minimizing operational risks. Moreover, digital twins augment traditional BI approaches by providing dynamic, context-aware insights for more informed decision-making. The real-time nature of DTs empowers decision-makers. Whether optimizing investment portfolios or evaluating

loan applications, DT-provided insights inform strategic choices. For instance, an asset management firm could use a DT to assess the impact of geopolitical events on investment performance. The ability to visualize complex data fosters informed decisions. In addition, DTs can enhance customer satisfaction. By understanding individual behaviors, financial institutions can customize services. For instance, a digital twin of a retail bank's mobile app could identify pain points in the user journey, leading to smoother interactions. Personalized recommendations, based on DT insights, can potentially strengthen customer loyalty and reduce churn.

In section 4.3, we described possible challenges of DT technology incorporation in financial services. As a result, the following challenges were discovered: "Data Privacy, Security, and Regulation", "Cost of development and maintenance", "Relevance", and "Reliability".

Creating a comprehensive digital twin requires integrating diverse data sources. Ensuring data accuracy, consistency, and relevance is challenging. Financial institutions must address data governance issues to ensure the effectiveness of DTs.

DT implementation demands significant resources, including financial, technical, and human. Developing and maintaining the DT, along with the necessary infrastructure, can require significant financial budgets. Scalability can be another concern, and as financial organizations expand, scaling DTs to accommodate growth becomes complex.

These findings partially correlate with other researches findings. DT in parallel with AI and IoT technologies face such challenges as data standardization, data management, and data security, as well as barriers to its implementation and legacy system transformation (Attaran & Celik, 2023). In summary, digital twins can open new opportunities for the financial sector, however, their successful adoption requires addressing challenges while maximizing benefits. By understanding use cases, leveraging DT-provided insights, and navigating implementation obstacles, financial companies can make optimal use of this technology.

5.2 Limitations

The validity of a study denotes the trustworthiness of the results, to what extent the results are true and not biased by the researchers' subjective point of view (Runeson & Höst, 2009).

Construct validity reflect to what extent the operational measures that are studied really represent what the researcher have in mind and what is investigated according to the research questions. If, for example, the constructs discussed in the interview questions are not interpreted in the same way by the researcher and the interviewed persons, there is a threat to the construct validity (Runeson & Höst, 2009). We partially addressed this threat by including additional clarifying questions to the interview guide that attempt to ensure common understanding between the researcher and a case study participant. Additionally, the interview notes taken by the researcher were shared with interview participants to ensure common understanding of interview results.

Internal validity is of concern when causal relations are examined. When the researcher is investigating whether one factor affects an investigated factor there is a risk that the investigated factor is also affected by a third factor. If the researcher is not aware of the third factor and/or does not know to what extent it affects the investigated factor, there is a threat to the internal validity (Runeson & Höst, 2009).

Examples of ways to improve validity are triangulation, developing and maintaining a detailed case study protocol, having designs, protocols, etc. reviewed by peer researchers, having collected data and obtained results reviewed by case subjects, spending sufficient time with the case, and giving sufficient concern to analysis of "negative cases", i.e. looking for theories that contradict your findings (Runeson & Höst, 2009).

Internal validity concern was partially mitigated in this study by triangulation and having collected data and obtained results reviewed by case subjects. The data collected for this case study included three sources: internal company data, publicly available information and researcher's analysis notes, and interviews. As mentioned earlier, the interview notes were shared with interview participants to ensure that there are no explicit factors that would extensively affect research results that are unknown to the researcher.

External validity is concerned with to what extent it is possible to generalize the findings, and to what extent the findings are of interest to other people outside the investigated case. During analysis of external validity, the researcher tries to analyze to what extent the findings are of relevance for other cases (Runeson & Höst, 2009). Due to the inherent limitations of case study approaches, the results have limited generalizability. They rely on the expertise of employees from the participating company and the study's specific context, which may restrict the applicability of our results. However, for case studies, the intention is to enable analytical generalization where the results are extended to cases which have common characteristics (Runeson & Höst, 2009). Thus, the results of our study can potentially be applied to companies that work on services to similar to FinPay such as payments.

Reliability concern is related to the extent the data and the analysis are dependent on the specific researchers. Hypothetically, if another researcher later on conducted the same study, the result should be the same (Runeson & Höst, 2009). To mitigate this concern, we partially addressed it by conducting internal document research and relying on internal as well as publicly available information about the company to enhance reliability.

Case studies, while valuable for in-depth exploration, have limitations when it comes to generalization. Because we focused on specific contexts and cases of a FinPay company, findings may not apply universally. In summary, it is not possible to draw broad conclusions about the whole finance industry solely from one company's case study results.

6 Conclusion

This thesis aims to explore the use cases of DT technology and assess its associated benefits and challenges. The research involved analyzing FinPay's internal documents, conducting interviews, and applying thematic analysis. The internal documents research helped to shape the idea of FinPay company and its services. The data was collected by conducting semi-structured interviews with specialists who had experience working at FinPay company. The collected data was analyzed using the thematic analysis method. As a result, four use cases were defined - "Risk Management", "Business Intelligence", "Marketing", and "Monitoring". In addition, we explored the benefits that were identified during data analysis: "Risk Mitigation", "Enhanced Decision Making", "Improved Customer Retention", and "Reliable Infrastructure". Finally, the case study results included an exploration of the possible challenges of DT technology incorporation in financial services. As a result, the following challenges were discovered: "Data Privacy, Security, and Regulation", "Cost of development and maintenance", "Relevance", and "Reliability". The thesis also includes descriptions and examples for each use case, as well as benefits and challenges, proposing value to financial companies.

Considering future work on this topic, there are several paths to study. Firstly, more specialized use cases can be identified beyond those described in this work. Secondly, researchers can consider the ethical dimensions of DT technology. Explore how it impacts customer privacy, fairness, and bias. By addressing these concerns, responsible and transparent deployment of DT solutions can be ensured. Thirdly, the assessment of how DT technology can be seamlessly integrated with existing legacy systems within financial companies can be conducted. This involves understanding compatibility, migration strategies, and minimizing disruption during adoption. Furthermore, as scalability and performance are critical, the challenges related to handling large volumes of financial data can be investigated in the context of DT incorporation. The field of DT technology is dynamic, and understanding the emerging trends and as well as interdisciplinary research approach is crucial for future work.

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Appendix

I. Interview Guideline

Research Questions:

RQ1: What are some potential use cases of DT for financial services?

RQ2: What benefits can DT bring to financial services?

RQ3: What are the challenges of using DT in financial services?

Materials, software, and environment: a laptop with an online version of this document; an online consent form; a Google Docs file with questions; a Google Docs file for notes; installed Microsoft Teams; a charger; the headphones; a glass of water; 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 objective is to research how Digital Twin can be used in financial services. The study aims to explore the potential implementation of Digital Twin technology at the company FinPay, including use cases, benefits, and challenges. During the study, the 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 with a request to sign before the interview. Save a file.
2. Send a Microsoft Team invitation or a link to the participant.
3. Right before the interview: Check the availability of the materials (see materials above)

During the interview:

1. Welcome the participant.
2. Thank them for participating in the study.
3. Introduce yourself.
4. Introduce the research (see introduction part above).
5. Ask the participants if they have any clarifying questions about the study.
6. Start video recording and transcription.
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. Make notes if needed.
9. Ask additional questions.
10. Stop recording.
11. Thank the participant again.

After the interview:

1. Save Microsoft Teams auto-generated transcript. Delete a recording.

II. Consent Form

Study title: Digital Twin Technology in Financial Services

Researcher: Azhar Kazakbaeva, 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 objective is to research how Digital Twin can be used in financial services. The study aims to explore potential use cases, benefits, and challenges of implementing Digital Twin in financial services. During the study, the 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 at FinPay company
- 3) be a fluent English speaker.

Expected duration of the study: The study will take 30-45 minutes of your time.

Risks and Benefits: There are no risks associated with this research in particular. There are no direct benefits to participants, but the research of possible use cases for subsequent study of Digital Twin technology applications is conducted.

Privacy and Confidentiality: 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 afterward. 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 (azhar.kazakbaeva@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

Hello! Thank you for participating in the study! As I mentioned earlier, I am researching the Digital Twin technology in financial services. To proceed with the meeting, I would like to start the recording; then, I am going to walk you through the Consent Form, which will take 2 minutes, and ask for your verbal consent to participate in the study. Then I am going to ask you the questions. Does it sound good to you? Do you have any questions for me?

IQ1: What is your understanding of DT in services?

IQ2: What use cases do you see for DT technology for providers of financial services?

IQ3: What is the value of having DT, and who will benefit from it?

IQ4: What technologies can be used to enable the usage of DT?

IQ5: What impact would DT usage have on the business?

IQ6: What are the potential challenges of the implementation of DT technology in financial services?

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Azhar Kazakbaeva

11/08/2024