Master's thesis

Master's Programme in Computer Science

Software Development in the Fintech Industry: A Literature Review

Saara Koskipää

November 14, 2022

Faculty of Science

University of Helsinki

Contact information

P. O. Box 68 (Pietari Kalmin katu 5)
00014 University of Helsinki,Finland

Email address: info@cs.helsinki.fi
URL: http://www.cs.helsinki.fi/

HELSINGIN YLIOPISTO – HELSINGFORS UNIVERSITET – UNIVERSITY OF HELSINKI

Tiedekunta — Fakultet — Faculty	Koulutusohjelma — Utbildningsprogram — Study programme
Faculty of Science	Master's Programme in Computer Science

Tekijä — Författare — Author

Saara Koskipää

Työn nimi — Arbetets titel — Title

Software Development in the Fintech Industry: A Literature Review

Ohjaajat — Handledare — Supervisors

Dr. Petri Kettunen

Työn laji — Arbetets art — Level	Aika — Datum — Month and year	Sivumäärä — Sidoantal — Number of pages
Master's thesis	November 14, 2022	54 pages

Tiivistelmä — Referat — Abstract

Background: The digital transformation of the financial industry lead by technological advances, together with changes in regulations, have created opportunities for companies to provide innovative new financial services. Fintech applies latest technological innovations to provide better and more efficient financial products and business models, disrupting the traditionally rigid banking industry. Objective: The objective of this study was to find out what kind of digital services are provided by the fintech industry, what software or technology related competencies and skills are needed in the development of fintech software, and the special requirements of fintech software. Method: The method of this study was systematic literature review. Following the defined review protocol, 31 primary studies published between the years of 2015 and 2021 were identified as relevant for this review by queries to three scientific databases. The selected primary studies were categorized by services, competencies and requirements. Results: Most of the identified digital services were payment applications but also robo-advisors, budgeting tools and compliance automation tools were found. The technologies and related skills extracted from the studies were divided to software development skills and data science skills and further categorized. Compliance with laws and regulations and various reporting and auditing practices were found to be unique domain requirements for fintech. Security was the most mentioned non-functional requirement of a financial system. Conclusions: Fintech is a cross-disciplinary field with unique requirements for business critical software. However, research on fintech software development is still limited.

ACM Computing Classification System (CCS)
General and reference → Document types → General literature
Applied computing → Law, social and behavioral sciences → Economics

Avainsanat — Nyckelord — Keywords

fintech, open banking

Säilytyspaikka — Förvaringsställe — Where deposited

Helsinki University Library

Muita tietoja — övriga uppgifter — Additional information

Software study track

Contents

1 Introduction

1.1 Motivation

Digitalization of services and society has been advancing rapidly during the last two decades. The advances in technology, the ubiquitousness of mobile devices, and fast and reliable network connections have enabled a digital transformation of services across industries. In many fields, the platform economy and new ways of providing customer services have changed the ways of doing business profoundly. Companies such as Über and Lyft can provide transportation services to customers without directly employing any drivers or owning any vehicles. Traditional institutions such as banks do not need as many brick and mortar offices for customer service anymore because their customers have moved to use the services over the Internet with online banking. Customers have become accustomed to a good user experience and high availability of services regardless of time and place. Customers have become accustomed to a good user experience and high availability of services regardless of time and place.

Digital transformation is creating new business models and affecting organizations on multiple levels from operations and company culture to the provided services and products. The goals of digital transformation are increased efficiency, more agile business practices and better customer experience. It is forcing established businesses to adopt smart digital technologies while also providing opportunities for startups to innovate and develop new services.

Fintech (financial technology) industry provides innovative new financial services that compete with and supplement traditional financial institutes and financing methods. Schueffel [Sch16] defines fintech as "a new financial industry that applies technology to improve financial activities". The ongoing digitalization of banking services, along with new regulations such as the Payment Service Directive in the EU that have forced financial institutions to open up their customers' data and transactions to third-party service providers, have opened new opportunities for fintech companies to create new services for the users [Üns+20]. Even mobile platform and device companies are integrating fintech applications such as mobile wallets in their products. Customer expectations for services have also changed [Üns+20] with the rapid development of smartphones. Customers expect to

have digital services that are easy to use and available at any time and location.

1.2 Research problem and questions

Fintech is a relatively young, cross-disciplinary business field and both startups and established financial sector companies need competencies at least from technology, finance and business management sectors. Fintech applications provide a wide variety of services in multiple categories such as payments and transactions, advisory services, financing, and compliance. The innovative applications and business solutions rely heavily on software development and utilize new technologies such as blockchain, thus requiring various technical skills from the developers as well.

The goal of this thesis was to find out what kind of technologies are behind fintech innovations and what kind of skills and competencies are needed in fintech software development. In this review, the focus was on hard competencies such as technical skills, although arguably soft competencies such as social skills and team work are also needed in modern software development. We also wanted to study the specific requirements and regulations that are possibly unique to fintech applications.

Based on this wide interest in fintech software, the research questions were formulated as follows:

RQ1: What kind of digital services are developed and provided by the fintech industry?
RQ2: What software or technology related competencies and skills are needed in the production of fintech applications?
RQ3: What special requirements need to be considered in fintech software development?

The selected method for the study was a systematic literature review. The goal of a systematic literature review was to answer these three research questions by finding and analyzing relevant primary studies concerning software development in fintech.

The rest of this thesis is organized as follows: Chapter 2 provides general background and history of the fintech domain and presents previous findings concerning fintech applications. Chapter 3 presents the systematic literature review protocol used in this thesis. The results of the review are categorized and analyzed in chapter 4. Chapter 5 provides discussion about the study results and chapter 6 contains the summary and final conclusions

about the study subject.

2 Background

2.1 Digital transformation in the financial services industry

Vial [Via19] defines digital transformation as "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies". At a high level, digital transformation is then about transforming processes to take advantage of new technologies. For organizations to remain competitive in the digital world, technology itself is only a part of the transformation process [Via19]. Digital transformation affects organizational structures, management, products and business practices as well [Via19] [MHB15].

Matt et al. [MHB15] describe the four dimensions of digital transformation affecting companies. The first dimension is the use of technologies and the company's ability to exploit them. Secondly, the adoption of new technologies can lead to changes in the company's value creation by providing new opportunities for developing services outside of the core business. These changes require organizational structural changes to support the new digital activities. Finally, the fourth dimension that enables but also limits the previous three is the ability to balance the diminishing old core business and the financing of the new innovations. Matt et al. also point out the changing skillset that is needed in the transformation process itself and for operations after the transformation [MHB15].

The financial services sector comprises of institutions that provide, for example, retail banking, accounting, financing, investment, credit and insurance services, as well as supporting services for those operations. In the financial services industry, digital transformation provides opportunities for established financial institutions, new fintech companies, and big technology companies such as Amazon and Google which are also entering the financial services area. Through digital transformation, existing financial services can be provided more efficiently, innovative new products and services can be be offered to customers, and at the same time companies' business processes are digitalized and the ways of working are changing profoundly [But20].

2.2 The history of fintech

It has been suggested that the term fintech originated from a project by Citibank in the 1990's but the first definition of fintech was in fact already presented in an scholarly article by Abraham Leon Bettinger, a Vice President of the Manufacturers Hanover Trust bank in 1972 [Sch16]. As a research topic area, fintech is relatively new. Preliminary queries made in research databases for this literature review indicated that the research in the field started to gain momentum around year 2015 and the bulk of the studies on the subject have been published in recent years. The same phenomenon can be seen in Google searches of "fintech" that grew exponentially from 2015 onwards [Sch16].

The history of technology in the financial industry is, however, much longer and the evolution of fintech has always been tightly tied to the continuing advances in technology. According to Leong and Sung [LS18], the first Trans-Atlantic cable in the 1850's provided a faster way of communication between continents. The communication time between North America and Europe was reduced from several days to just 17 hours. Technological innovations like mainframe computers and telex communication later enabled financial technology services such as ATMs and the global SWIFT payment system [LS18]. In 1995, the first online consumer banking system was developed by Wells Fargo [PS21].

The economic turmoil in 2007-2008 caused consumers to lose trust in traditional banks and strengthened their opinion that technology firms would handle their cash better [PS21]. Ubiquitous smartphones and the development of more advanced Application Programming Interfaces (APIs) were also important in this phase of the evolution of fintech. The changes in regulations in many parts of the world forced financial institutions to open their previously restricted APIs to third parties for sharing customer data [DS19]. APIs provide access to financial institutions' customer data such as transactions and monetary balances. The key features at this phase of fintech were also the rapid rate of technology development and the "change in the identity of financial service providers" [PS21]. Recently, the Internet and the Internet Of Things have dominated fintech industry development and according to Leong and Sung [LS18], the next phase will be defined by data technologies.

In the year 2009 the first cryptocurrency, Bitcoin, was released. Cryptocurrencies provided a decentralized way of making payments. By eliminating the middleman, payments could be made regardless of time and location and with lower transaction fees. Cryptocurrencies are considered secure and transparent payment methods with fewer risks for fraud.

Bitcoin's value has been very volatile and the uncertainty about changing regulations concerning digital currencies has made it also more difficult to predict [DS19].

The ability to collect and process data are essential for the current development stage of fintech. AI solutions are speeding up analyzing processes that used to be done manually [PS21]. The new fintech startup companies have the advantage of building the right systems from the start while established financial institutions such as banks have the burden of legacy technologies. They also face stricter regulations compared to the newcomers that in at least some countries have been operating outside existing regulations [PS21].

In the EU, the General Data Protection Regulation (GDPR) and the revised Payment Service Directive (PSD2) specifically gives the ownership of personal data and the decisions about how it is being used and who can access it to individuals. Using this data, fintech and other third party companies can create new services that match the consumers' needs [DS19]. Similar changes in regulation and opening of previously restricted banking APIs to third party developers have been happening globally in recent years.

Fintech companies can either compete or collaborate with existing financial institutions [PS21] [Gec+14]. In software development, fintech startups and other technology companies can develop new services using agile and lean methods, resulting in shorter time to market and reduced costs compared to the rigid processes of the traditionally conservative financial services industry [Gec+14]. Traditional financial institutions usually provide multiple services on legacy systems using old monolithic architectures, while fintech companies can concentrate on building individual new services on modern infrastructure and technologies [Kil+19]. The competition has also forced traditional institutions to adopt more agile ways of working in the development of services.

2.3 The definition of fintech

In the first known mention of "fintech" in literature, Abraham Leon Bettinger wrote that "FINTECH is an acronym which stands for financial technology, combining bank expertise with modern management science techniques and the computer" [Sch16]. Schueffel [Sch16] states that the term fintech has been used in many contexts but inconsistently and that the term does not have any scientifically agreed upon definition. It is used to reference both the technology that is used to support the financial services and the industry that is creating financial services. The motivation for Schueffel's research was to create a definition that could be used as a reference in scientific work but also define the idea

of fintech to practitioners. To form a basis of clear communication there needs to be a common understanding about the term. Based on the semantic analysis of 13 previous peer-reviewed definitions, Schueffel defines fintech as "a new financial industry that applies technology to improve financial activities".

Leong and Sung [LS18] also argued that there has been a lack of commonly agreed definition of fintech and proposed their own. Their definition was based on the responses gathered from over 200 people with different backgrounds ranging from students to business professionals who the researchers had met on different occasions. The respondents were asked "about their understanding of FinTech". Despite their backgrounds, the subjects were found to have a very vague idea of the concept of fintech. Leong and Sung define fintech as "a cross-disciplinary subject that combines Finance, Technology Management and Innovation Management". They also go further and elaborate fintech as any innovative ideas that apply technology solutions to improve financial service processes. The ideas could lead to new business models or businesses. Following that definition and elaboration, platform businesses such as Über could be considered fintechs. Über uses technology to provide an innovative transportation service and an improved financial solution for ordering and paying for the service [LS18].

In this thesis, we follow Leong and Sung's [LS18] definition of fintech as applying technology solutions to improve financial service processes (table 2.1) and separate it from the companies providing financial technology services (fintech companies, table 2.2). Being a relatively young research topic, finding a commonly accepted and understood definition for the term fintech seems to have been difficult in scientific papers about fintech. In addition to the definition, the term also appears in multiple slightly different written forms in literature. The most common are FinTech and fintech, but also Fin-Tech, Fin-tech and fin-tech can be found in research papers and popular literature alike. For this thesis, the form fintech was chosen to be used.

Because financial institutions are heavily regulated, they face particular challenges concerning data governance and regulatory compliance. To solve these challenges, fintech subfields of Regulatory Technology (RegTech) and Supervisory Technology (SupTech) are also emerging to handle regulatory compliance and reporting, risk analysis, and supervisory processes that are an important part of the industry. Enabling technologies for these subfields are artificial intelligence methods, distributed ledgers and smart contracts along with innovative cloud technologies such as edge and fog computing [But20]. Table 2.1 combines together the frequently used terminology related to fintech subfields. Other

fintech related terminology used in this thesis is collected in table 2.2.

Table 2.1: Fintech subfields and terminology

Abbreviation	Term	Explanation
Fintech	Financial technology	Production of efficient and innovative financial services utilizing latest technology. Also used in literature in reference to a financial technology company (table 2.2) or the fintech industry.
TechFin	–	An established big technology company (Google, Amazon) providing fintech services although the core business of the company has been something other than financial services.
RegTech	Regulatory technology	RegTech solutions provide automation for compliance with regulations. RegTech is also sometimes considered as a completely separate field from fintech since it does not directly provide financial services. However, in this thesis it is considered as a part of fintech field since regulatory compliance is vital to fintech industry and the technologies being used are overlapping.
SupTech	Supervisory technology	SupTech innovations automate the gathering and monitoring data and enhances the supervisory processes needed for regulatory compliance.
InsurTech	Insurance technology	The application of fintech solutions in the insurance business context. Similarly to RegTech, it may also be considered an individual field although its roots are in fintech. In this thesis, it is considered as a part of fintech.
WealthTech	Wealth Technology	Automated wealth management services with the use of new technologies such as AI and Big Data.
DeFi	Decentralized Finance	Providing financial services without a centralized control agency such as bank.

Table 2.2: Terminology used in this thesis

Term	Definition
Financial services industry	An industry that enables financial transactions. It comprises of institutions that provide, for example, retail banking, accounting, financing, investment, credit and insurance services, as well as supporting services for those operations.
Fintech services	Efficient financial services provided with the use of latest technology and software.
Fintech company	A company that uses technology to provide improved and more efficient financial services to consumers and other businesses.
Fintech industry	An industry that comprises of fintech companies.
Fintech solution	Way of completing financial operations and providing services through latest technology and software.
Fintech application	A computer program used for completing transactions or other processes in finance.
Fintech software	Software used in fintech applications.

The big technology companies such as Google and Facebook are also sometimes called TechFins (table 2.1). While fintech refers to financial companies and start-ups using technology for financial services and products, TechFins are established software or technology companies that have started offering financial services in addition to their core business [PS21]. Those companies have already collected vast quantities of data of their current and potential customers and also have already developed means to utilize that data. That data provides them a clear advantage compared to other fintech companies.

Financial technology companies have drawn customers from traditional banks and enabled customers to choose services from multiple banking service providers instead of just one provider [DS19]. Due to online banking services, banks have also lost physical access to customers who do not visit physical banks anymore. Banks have begun outsourcing a part of their activities to fintech companies and co-operating with them instead of only competing with the newcomers. A bigger market threat for the traditional institutions seems to be the existing platforms provided by TechFins that already have a large established customer base. With the gathered customer data, those platforms can provide a superior user experience while offering banking services among their other products. On the other hand, banks also already have the customers' financial data to utilize and the regulatory experience that is needed in the financial industry [DS19].

As discussed previously in this chapter and presented in table 2.1, various other "Techs" can be considered either as subfields of fintech or completely separate phenomena, depending on the scope of the definition. Traditional fintech applications rely on centralized authority and control while decentralized finance (DeFi) including cryptocurrencies do not have a central control source. That has led to suggestions in literature about DeFi being a separate field from fintech. In this thesis, cryptocurrencies are considered as part of fintech as they apply innovative technology to provide improved financial services.

2.4 Common fintech applications

Fintech companies' business models include wealth management, lending, payment and insurance services and capital market models [PS21]. Fintech solutions for handling, borrowing, transferring and owning money are also enabling better financial inclusion for people who have previously not had access to banks and bank accounts. A customer-centric mindset of fintech companies also enforces this inclusion [PS21]. In the developing world, fintech solutions such as mobile banking provide banking services for areas that

otherwise lack a physical banking infrastructure [DS19].

The most active areas of fintech companies are blockchain technology and its applications such as cryptocurrencies and smart contracts, open banking through the usage of APIs, Insurance technology (InsurTech), Regulation technology (RegTech), robo-advisors, unbanked services for the financially insecure, crowdfunding, and mobile payments [PS21].

Leong and Sung [LS18] classify fintech applications into four categories based on the way they can create business value. Payments concentrate on cashless payment methods and topics such as blockchain, a key technology in smart contracts and digital currencies. Advisory services are services such as asset management, insurance and investment advice and customer support. In this category, gathering and processing data play a big role in advisory products with novel technologies being utilized ranging from wearable computers and IoT to machine learning algorithms. In the financing category, fintech applications provide different ways of borrowing and lending. Crowdfunding and peer-to-peer lending are some of the types of alternative funding. New sources of funding also promote financial inclusion and fairness. The fourth category is compliance where fintech applications support compliance processes and enhance regulatory processes [LS18].

In the European Union, PSD2 has obligated banks to open their Application Programming Interfaces (APIs) for third parties. Those companies can utilize the APIs in multiple ways, such as handling web payments. The open APIs form an essential part of fintech called open banking. Outside the EU, the UK has pioneered with a similar concept called simply Open Banking. Commercial banking aggregation models have also been developed in the US [DS19].

In open banking, the customers' financial data and transactions are shared with the different parties through APIs. The APIs have been used previously in closed settings, for example, for connecting to credit card payment networks. In open banking, the APIs are used in more versatile ways providing data and services that the institute considers worth offering to other companies, such as general data about transactions or individual user's money balances [DS19].

The three key areas of technological advances that have been beneficial for technology-based financial services are increased connectivity, low costs of computing and data storage, and as a result of these the vast amounts of data that can be captured, stored and analyzed [Fey+21]. As a result, new business models have evolved to utilize that data. Connectivity has increased due to the Internet and mobile technology. Better connections have enabled transferring data and interacting remotely. Data created through those connec-

tions can be affordably stored using cloud storage and analyzed using AI tools. Data can be gathered from various different sources such as social media interactions, web browsing history, and location data from mobile devices. That data can then be used to target customized and personalized needs. Big data can be used for credit analysis, risk management and customer service, to name a few areas. Existing large customer bases with detailed customer data of companies such as Facebook or the existing platform to integrate new services and APIs provided by Amazon give these big technology companies an advantage in competition [Fey+21].

3 Research design and method

In this chapter, the research method used for this study is presented. First, a motivation behind the selected research method is explained. Then the research process is described with a brief background explanation of the method and a detailed description of the particular protocol used for this review. For this thesis, a systematic literature review was conducted based on the guidelines defined by Kitchenham [Kit04].

Each step of the review protocol is explained and documented in detail to ensure that the process and the selection of the publications can be replicated. The queries, selected data sources and motivations behind them are presented, followed by exclusion and inclusion criteria on each round of the document selection process. The validity and quality of the selected studies are then evaluated based on a criteria developed for this process.

3.1 Motivation for systematic literature review as a research method

A systematic review is conducted in order to summarize all existing information about a phenomenon [KC07]. The research work for the review is conducted in a thorough and unbiased manner. As a result, a systematic literature review provides general conclusions about the phenomenon under study and can guide future research as well by identifying potentially missing important research from the subject.

The goal of a systematic literature review is to identify as many primary studies as possible concerning the research question using an unbiased search strategy [Kit04] [KC07]. An important part of the work is to define a review protocol that will be followed meticulously. The review protocol described by Kitchenham [Kit04] includes the defining of the research questions and describes the method that will be used for answering them. The protocol aims to ensure that all relevant primary studies are included without a bias, that the process can be replicated to verify the set of selected studies, and that the validity of the results can be assessed.

The goal of this thesis is to provide an understanding of the current situation on fintech software development and the special requirements of the domain, and to point out the

needs for particular talents and competencies needed in the field. The research questions of this thesis (also presented in chapter 1) are as follows:

RQ1: What kind of digital services are developed and provided by the fintech industry?
RQ2: What software or technology related competencies and skills are needed in the production of fintech applications?
RQ3: What special requirements need to be considered in fintech software development?

The systematic literature review for this thesis was conducted by following the method and guidelines described by Kitchenham [Kit04]. The work consisted of the following steps:

1. Identifying the relevant research/studies
2. Selecting the studies for the review by using detailed inclusion/exclusion criteria
3. Assessing the quality of the selected studies
4. Extracting data from the selected studies
5. Synthesizing the extracted data

3.2 Description of the review protocol

A systematic literature review starts with developing a research protocol. Following the defined protocol aims to ensure that the study process is rigorous and repeatable. For this thesis, the first step in this protocol was to define the research questions presented in the section 3.1. Three research questions concerning fintech applications, requirements and competencies were formulated as a frame to guide the process. Next, the search strategy and scope were defined to find all relevant primary studies on the subject. The search strategy was constructed to include as many publications as possible while also eliminating irrelevant results. Combinations of keywords were tested in multiple databases to find out which queries provided the most suitable results. The keywords were derived from the three research questions of this thesis (section 3.1) to limit the results to studies that concerned software development or fintech applications. The preliminary results of the queries in different databases indicated that a query string that was too specific would not be suitable to provide results to answer all of the three research questions. Hence, a query string that would provide a wide selection of results was selected. The query string

and its variations are presented in table 3.1.

A database-centric search strategy was selected for this study in order to find all of the possibly relevant studies to start the selection process with. The selected databases were IEEE Xplore, ACM Digital Library and Scopus. ACM Digital Library is a comprehensive collection of computing and information technology research literature. IEEE Xplore provides scientific publications spanning several decades from fields of electrical engineering, communications and computer science. Scopus is a curated abstract and citation database covering multiple disciplines. Although Scopus also contains the material found from the other two databases, the query filters and the different search algorithms of the databases prevented the majority of the results from being duplicates. The searches were not limited to a time period in order to include all of the possibly relevant studies. The query filters were slightly altered to fit the limitations of the particular databases. The queries contained keywords and the synonyms of the keywords or different variations in the written form combined with AND and OR operators. The details of the specific queries and databases where they were used are presented in table 3.1. The initial search queries using only the query string yielded a total of 1109 results as detailed in table 3.1.

3.2.1 Databases

The databases were selected by running trial queries in commonly used databases for software research. Based on the trials, IEEE Xplore, ACM Digital Library and Scopus were selected as the main data sources since they provided more efficient methods to create the query string and add filters compared to, for example, Google Scholar. The scope of the search was not limited to any specific time frame, although the results did confirm the currentness of the subject. The earliest paper selected after running the initial queries and first filtering of the results was from the year 2008 and only a few other papers were published before the year 2015.

3.2.2 Queries

The keywords were selected based on the research questions of this study (section 3.1). Queries for different databases were slightly modified depending on the limitations presented by the source database. Boolean operators OR and AND were used in order to include keywords and different synonyms. The selected databases handled plurals of the singular words automatically. The query strings are presented in table 3.1. In the ACM

Table 3.1: Query strings and number of results from the selected databases

Database	Query string (Scopus query string also includes the selected filters)	Before database filters	Results after applying filters
ACM DL	[[Abstract: fintech] OR [Abstract: "financial technology"] OR [Abstract: "fin-tech"]] AND [[Abstract: software] OR [Abstract: application]]	77	54
IEEE Xplore	("All Metadata":fintech OR "All Metadata":"financial technology" OR "All Metadata":"fin-tech") AND ("All Metadata":software OR "All Metadata":application)	201	189
Scopus	(TITLE-ABS-KEY(fintech OR "fin-tech" OR "financial technology") AND TITLE-ABS-KEY(software OR application*)) AND (LIMIT-TO(DOCTYPE, "cp") OR LIMIT-TO(DOCTYPE, "ar")) AND (LIMIT-TO(SUBJAREA, "COMP") OR LIMIT-TO(SUBJAREA, "ENGI")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE, "p"))	831	430
Total		1109	673

Digital Library, the whole collection (The ACM Guide to Computing Literature) was used in the search instead of limiting it only to the Full-Text Collection.

After running the initial query, filters were applied to limit the number of results to only potentially relevant papers (table 3.1). The filters were slightly different in each database but the most similar ones were selected. Scopus also provided a filter for the subject area that was used to select “Computer Science” and “Engineering” and leave out studies of, for example, medicine and social sciences since those subjects were not considered relevant for this review.

3.2.3 The search procedure

A summary of the search procedure is presented in figure 3.1.

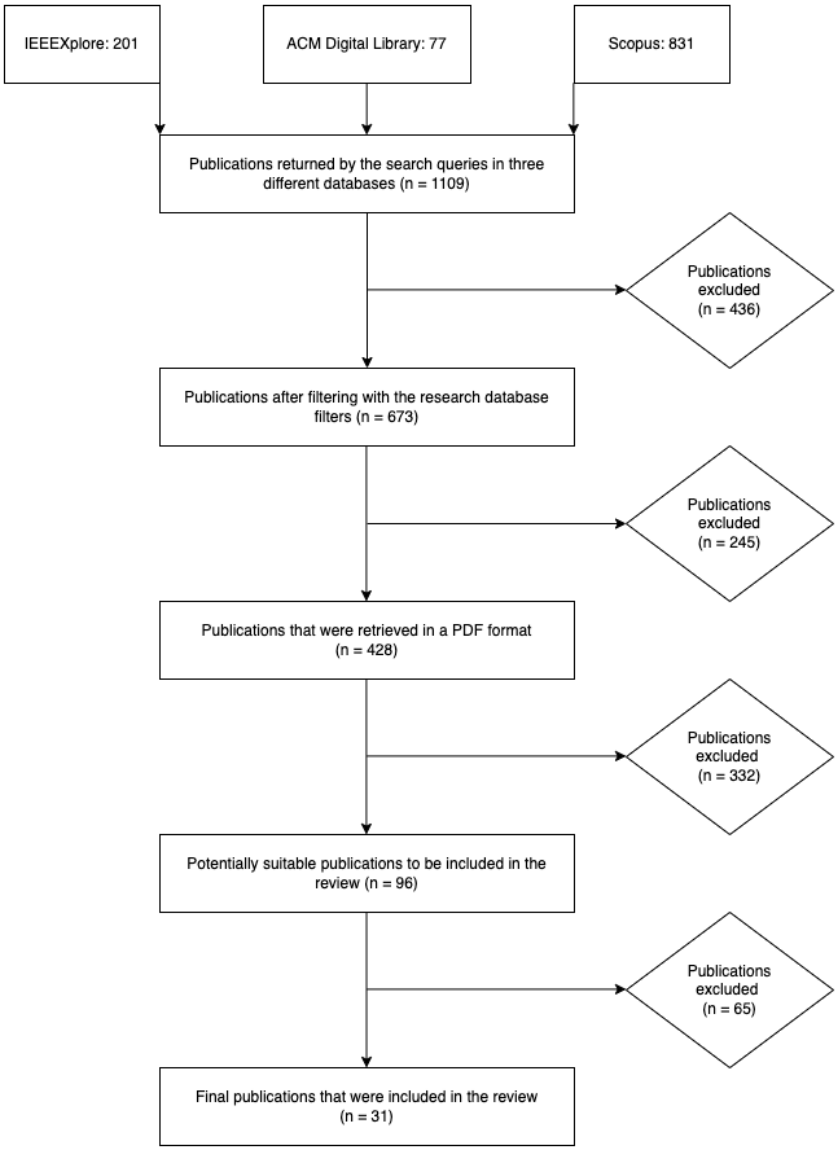

Figure 3.1: The selection process

Phase 1: Identifying all potentially relevant primary studies

After selecting the source databases and creating the query strings, the initial searches were conducted with 1109 results (table 3.1). After the initial query runs, filters provided by the databases were applied to the search results. This first inclusion and exclusion round was made based on the source type and the type of the result. The filters were

unique to the selected databases. In IEEEXplore, Magazines and Books were excluded as a source while Conferences, Journals and Early Access Articles were included as source categories. ACM Digital Library's inclusive filters were set to papers with type Research-Article, Article, Short Paper and Doctoral Thesis. This decision left out results with type Master's Thesis, Book, Extended-Abstract, Abstract and Keynote.

Scopus had more options in the filters. As topic areas, Computer Science and Engineering were selected. Results were limited to Conference Paper and Article types from sources Journal and Conference Proceeding. Lastly, only studies written in English were included. After these filters were applied, the three databases together yielded a total of 673 results.

Phase 2: Removing duplicates and retrieving articles

The references were exported to Mendeley Reference Manager software from the database search results. In the second phase the research papers were downloaded in pdf format for more detailed filtering. Before downloading the documents, duplicates (134) were removed from the references. 101 papers could either not be found or were behind a paywall and not accessible through the University's library services. 11 documents were found to be of the wrong type despite the selected filters and thus not downloaded. All in all, 428 full-text documents could be obtained for closer study.

Phase 3: Going through titles and abstracts

Next, the downloaded documents were assessed again based on their titles and abstracts. The goal of this step was to exclude papers that were clearly out of the scope of this study. First, the type and language of the publications were checked. Only papers written in English and of the same types that were used in the database filters were included. After passing this check the relevance of the content was evaluated. The following exclusion criteria were used:

Exclusion based on language or document type:
E1: Not in English
E2: Wrong publication type (e.g. master's thesis, bachelor's thesis, workshop, popular magazine article, talk, editorial), unpublished papers (content may still change)

Exclusion based on content:
E3: Literature reviews
E4: User studies
E5: The study subject is not fintech or fintech software development

E6: Algorithm studies without an implementation in application

Based on these exclusion criteria, 332 documents were excluded and 96 documents included for the next phase as potentially suitable publications for this review.

Phase 4: Selecting the primary studies

In the last phase the documents were subjected to more detailed evaluation. Inclusion criteria were set based on the three research questions of this thesis while the reasons for exclusion were the same as in the previous phase. The goal was to ensure that an individual publication can provide insight to at least one of the research questions. To be qualified, a study had to pass all exclusion criteria and fulfill at least one inclusion criterion.

Inclusion criteria:
I1: Related to fintech software development
I2: Concrete end-user application in the fintech field
I3: Related to special requirements or regulations of the fintech field

After these final considerations, 31 primary studies were selected as the material for this review. The complete search procedure is summarized in figure 3.1. The list of the selected literature is presented in table 3.2 along with an assumption about which research question of this thesis the study will help answer.

Primary studies		
Reference	Title	RQs
[CS19]	Enterprise Framework for Business Intelligence Tools on Cloud Computing Environment for Investment Platforms	1, 2, 3
[DLC18]	Artificial Intelligence for Conversational Robo-Advisor	1, 2
[ASS19]	Smart Contracts in View of the Civil Code	3
[MK16]	A Payment Mediation Platform for Heterogeneous FinTech Schemes	1
[Üns+20]	Building a Fintech Ecosystem: Design and Development of a Fintech API Gateway	1, 2, 3
[Suk+17]	Design Concepts Smartcoop with Implementing Financial Technology	1
[Sur+18]	Financial Technology Integration Based on Service Oriented Architecture	1, 2, 3
[AI19]	The Design and Implementation of Trade Finance Application based on Hyperledger Fabric Permissioned Blockchain Platform	1, 2
[Bal+21]	DeepGRASS: Graph, Sequence and Scaled Embeddings on large scale transactions data	1, 2
[HFA21]	Go-Payment: Towards Cashless Payment System for Smart Village Application in Indonesia	1, 2
[YC19]	Transforming the Know Your Customer (KYC) Process using Blockchain	1, 3
[Rai+18]	A Blockchain Framework for Insurance Processes	1, 3
[Mes+15]	A Mobile Money Solution for Illiterate Users	1, 2
[DCL18]	AI Robo-Advisor with Big Data Analytics for Financial Services	1, 2
[CJW17]	Blockchain-based Payment Collection Supervision System using Pervasive Bitcoin Digital Wallet	1, 2
[OB17]	Cam-Wallet: Fingerprint-Based Authentication in M-Wallets using Embedded Cameras	1, 2, 3
[Nen17]	Construction of High-Availability Bank System in Virtualized Environments	2, 3

Primary studies, continued		
[WF21]	Contactless and Cashless Smart Vending Machine Integrated with Mobile Device	1, 2
[Fan+18]	Secure Authentication Protocol for Mobile Payment	1, 3
[Har+18]	The Implementation of E-money in Mobile Phone: A Case Study at PT Bank KEB Hana	1, 3
[Has+19]	VoiceNote: An Intelligent tool for monetary transactions with integrated voice support	1, 2, 3
[ADE21]	A Secure and Efficient Multi-Factor Authentication Algorithm for Mobile Money Applications	2
[Her+21]	CEBRA: A CasE-Based Reasoning Application to recommend banking products	1, 2, 3
[Cam+17]	Finding Suspicious Activities in Financial Transactions and Distributed Ledgers	3
[ZLY20]	How to Integrate Financial Big Data and FinTech in a Real Application in Banks: A Case of the Modeling of Asset Allocation for Products Based on Data	1, 2
[Xu+20]	PPM: A Provenance-Provided Data Sharing Model for Open Banking via Blockchain	2, 3
[Deg19]	Regulatory Challenges and Solutions for Fintech in Turkey	3
[AAE21]	SBM: A Smart Budget Manager in banking using machine learning, NLP, and NLU	1, 2
[Jin+19]	FinExpert: Domain-Specific Test Generation for FinTech Systems	2
[Wan+18]	FACTS: Automated Black-Box Testing of FinTech Systems	2
[Wan+21]	FinFuzzer: One Step Further in Fuzzing Fintech Systems	2

Table 3.2: Systematic literature review primary studies

3.2.4 Assessing the quality of the selected studies

The studies in the review material were evaluated against a set of quality criteria (table 3.3). The grading of the selected primary studies was done on a scale of 0 to 5. Each question in the set would give 0 (no), 0.5 (somewhat) or 1 (yes) points for the study, depending on how well the content of the study fared with the assessment question. Question number four was found not to be applicable to all of the studies, for example, papers describing the implementation of an application. The selected studies scored between 2 (two papers) and 4 points. Majority of the papers (27 out of 31) failed to receive any points from question number five concerning the discussion about the credibility or limitations of the study.

Table 3.3: Quality assessment criteria

Question	1 (Yes)	0.5 (Somewhat)	0 (No)
1. Is the goal of the study stated clearly?	31/31	0/31	0/31
2. Is the rationale for the study presented and explained?	31/31	0/31	0/31
3. Is there a description of the study design or proposed/implemented application?	28/31	1/31	2/31
4. Is there data about the findings of the study and are the findings reported clearly?	19/21	1/21	1/21
5. Are the limitations of the study and/or the credibility of the results discussed?	0/31	4/31	27/31

3.2.5 Classification of the studies

The data extraction phase of the literature review began by reading the selected studies in detail and creating categories based on the topics of the studies and the research questions of this thesis. Keywords were extracted from the material and the keywords were then combined in the categories.

Five categories were created for the first classification of the studies. The categories were created based on the research questions of this thesis (section 3.1) and were as follows:

RQ1:

1. Applications and services: The study presents a fintech application or service (e.g. a mobile payment application).

RQ2:
2. Technologies: The study describes technologies used in fintech applications or services (e.g. blockchain).
3. Competencies: The study presents competencies or skills needed in the development of fintech software systems (e.g. software testing).
RQ3:
4. Non-functional requirements: A non-functional requirement of a software system is mentioned in the study (e.g. security).
5. Domain requirements: The domain requirements of fintech software are discussed in the study (e.g. regulations).

Two separate classes were created for technologies and competencies (RQ2) in this step of the process. The requirements (RQ3) were also separated into two main categories as non-functional requirements were separated from domain requirements that cover regulations concerning financial software systems.

The studies were first classified to belong to at least one category out of the five main categories based on which research questions of this thesis (section 3.1) the research paper was related to. The relation of the primary studies to the research questions is shown in table 3.2. The main categories were then further divided into subcategories.

After the initial classification, the studies were categorized in a more detailed process in relation to the research questions as shown in the figure 3.2. The applications category was divided into subcategories by the functionalities of the application or system that the paper described. Subcategories were created for payments, robo-advisors, compliance automation and budgeting tools. Individual papers that did not belong to any of these subclasses were combined into their own subclass. Applications could belong to multiple categories and subcategories. The same application could, for example, be classified as a tool for automating compliance as well as a service provided for the customer as an application.

The competencies were studied by creating a concept map (figure 3.3) of keywords that were extracted from the papers while reading. The keywords were grouped and the groups were labeled with a skill. Only technical skills were considered when conducting the review while soft skills such as social skills and problem solving were not described in the material and were considered out of scope for this review.

Non-functional requirements were extracted from the studies by identifying keywords and

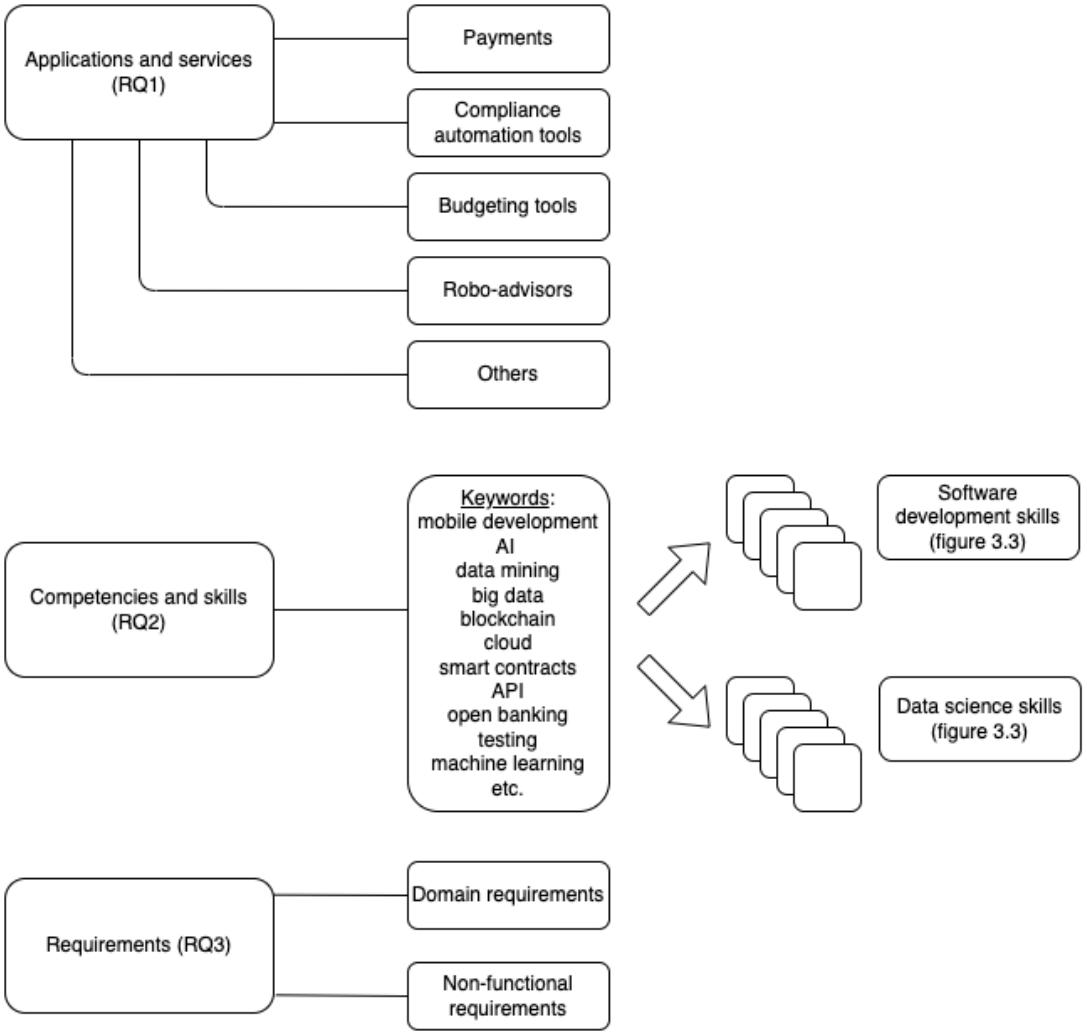

Figure 3.2: The classification of the primary studies

the reasoning behind the requirement in the system or application presented in the research paper.

The results of the analysis of the material are provided in chapter 4.

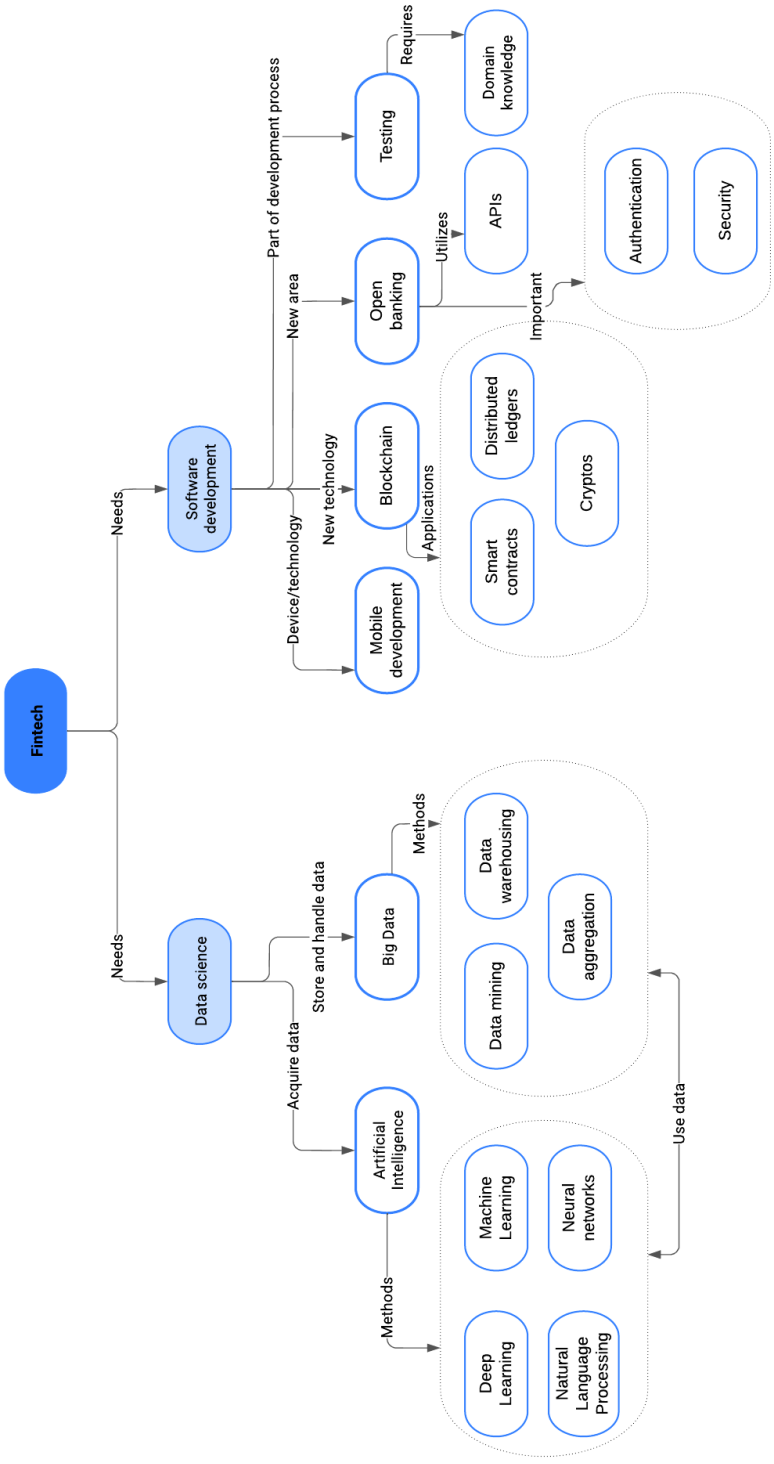

Figure 3.3: A high level concept map of competencies and skills

4 Results

After going through the review protocol steps, 31 primary studies (table 3.2) were selected for analysis and categorized. This chapter presents the data gathered in the research process and the results of the systematic literature review. First we provide some general findings of the material and then present the categorization of the data (figure 3.2) and the results in relation to the research questions. The relevant content of the individual research papers is briefly presented to justify the categorization.

4.1 General findings

The studies selected for this work were published between 2015 and 2021 with 24 of the 31 papers (77%) published between 2018 and 2021. This is in line with the overall upwards trend of research in the field described in section 2.2. The yearly distribution is presented in figure 4.1.

The institutions that the authors of the studies were affiliated to were from 21 different countries with the majority of the studies coming from Asian countries. Same group of authors were involved in all three publications about fintech software testing [Jin+19] [Wan+18] [Wan+21], and one other person was marked as an author for two publications concerning artificial intelligence and robo-advisors [DLC18] [DCL18].

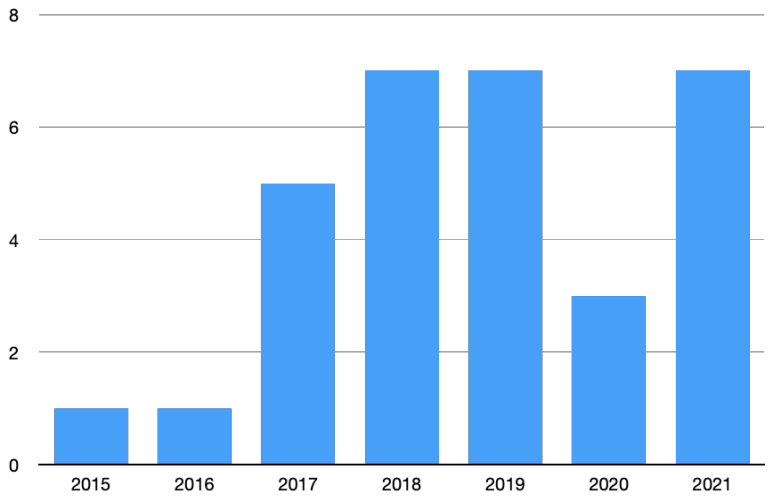

Figure 4.1: The number of studies by year

4.2 Non-functional requirements

Non-functional requirements of fintech software system were mentioned in 15 out of the 31 primary studies. The most assessed quality attribute was security with mentions in eight papers. Compliance was mentioned in five papers, privacy in four and performance in three. Availability was also addressed in two papers, the second one discussing especially the high availability requirement of financial systems. In addition to these requirements, reliability, usability, maintainability, interoperability, flexibility, robustness, responsiveness, and scalability were mentioned. The attributes and referencing studies are listed in table 4.1. Application specific functional requirements were not extracted from the review material. Since none of the studies under review was research about requirements, the attributes only needed to be mentioned in the paper as a quality of the fintech application or system.

Twelve of the thirteen quality attributes (table 4.1) were selected as requirements for the mobile money application developed by Ali et al. [ADE21]. Compared to the other studies that mentioned requirements, Ali et al. provided the most comprehensive description of the non-functional requirements of their system. They also provided security and performance analysis to ensure that the most important non-functional requirements were satisfied.

Security

Data confidentiality is an important part of security in financial services [Üns+20] [Rai+18]. Reliable and secure authentication is needed in applications that handle sensitive data and financial transactions [OB17] [Fan+18] [ADE21]. Data security is also required by different local and international laws and regulations, such as GDPR in the EU [Deg19].

Compliance

Companies providing financial services are regulated by the laws of the countries where they operate. Companies are required to make regulatory filings to both the authorities and the public regularly [CS19]. Technical innovations such as smart contracts must comply with the private laws concerning similar contracts defined in civil code [ASS19]. The provided services may be illegal in some countries [Has+19] [Sur+18] or require the companies to verify the identities of their customers [YC19].

Privacy

In addition to data security, privacy as a requirement in fintech applications ensures the compliance to applicable laws, for example GDPR in the EU [Her+21]. With open bank-

ing APIs, customer data that has previously been handled only in a closed system of a traditional bank becomes available to third parties and its privacy must be protected [Xu+20].

Availability

Customers' expectations for financial services have risen and those services should be available at all times. Possible interruptions in services create reputational and operational risks for banks [Nen17]. Availability is an important non-functional requirement for fintech services. Designing financial software systems for high availability ensures continuous service even if some parts of the system fail.

Performance

Banking software systems have strict performance requirements as the system response time cannot exceed a certain value [ZLY20]. This requirement emphasizes the effectiveness of the algorithms that are being used for solving complex equations. Ariffin and Ismail point out that good performance can be difficult to obtain in blockchain-based systems since every transaction requires consensus on agreed state among multiple participants [AI19].

Table 4.1: Non-functional requirements of fintech applications

Requirement	Papers (n)	References
Security	8	[Üns+20], [Rai+18], [OB17], [Fan+18], [Har+18], [Has+19], [ADE21], [Deg19]
Compliance	5	[CS19], [ASS19], [Sur+18], [YC19], [Has+19]
Privacy	4	[Har+18], [ADE21], [Her+21], [Xu+20]
Availability	2	[Nen17], [ADE21]
Performance	3	[AI19] [ADE21], [ZLY20]
Reliability	1	[ADE21]
Usability	1	[ADE21]
Maintainability	1	[ADE21]
Interoperability	1	[ADE21]
Flexibility	1	[ADE21]
Robustness	1	[ADE21]
Responsiveness	1	[ADE21]
Scalability	1	[ADE21]

4.3 Fintech domain requirements

Domain requirements describe the characteristics and needs of the domain [Her+21]. Domain requirements can be difficult to understand for the developers. The domain can have specific vocabulary that is clear to the domain experts but can be difficult to comprehend for the developers and cause misunderstandings. In fintech, data protection laws and regulations concerning financial transactions are such requirements that are defined strongly by the domain.

Financial institutions and banks around the world are usually heavily regulated and must comply with several laws and auditory requirements. The regulations apply to fintech companies as well when they perform regulated activities such as money transactions or when handling customer data. The regulations differ dramatically from one country to another. Especially international fintech companies have to be careful to comply with the particular regulations of all of the countries they operate in [Deg19].

Fintech companies must comply with Anti-Money Laundering (AMC) and Counter-Terrorism Financing (CTF) regulations [Deg19]. Know Your Customer (KYC) is a common policy that obligates banks to verify their customers' identities and the origin of funds [Cam+17] [YC19]. The purpose of these reqirements is to prevent money laundering and the financing of terrorism. Financial institutions are also required to report suspicious transactions and activities [Cam+17].

Fintech services utilize and handle sensitive personal data. Hence, data privacy laws such as the GDPR in the EU regulate how that data is processed, stored and protected [Deg19] [Her+21]. Also countries outside of the EU may have similar regulations.

Another field of interest is applying civil code to the applications of new technology. As explicit regulation is still lacking in many countries for cryptocurrencies and smart contracts, there is little experience in applying current law to them. Under certain circumstances, smart contracts may constitute a civil contract [ASS19].

Companies are required to provide frequent regulatory filings for transparency of their financial state to the public, government entities and investors [CS19]. This is not a unique requirement for fintech companies but concerns other businesses as well. However, fintech companies can be subject to audits by authorities for compliance of regulations concerning their business field [Deg19].

4.4 Fintech applications

The largest group of applications presented in the studies under review (table 3.2) were related to payments and other financial transactions. Other types of services were robo-advisors, budgeting tools, mobile banking application, a financial system for cooperatives, a Know Your Customer (KYC) application, a recommendation system for banking products and an asset allocation optimization tool for banks. Six tools for automation of the compliance processes were also presented. Table 4.2 shows the distribution of applications by category.

Table 4.2: Applications by type. Some applications belong to multiple categories.

Application type	Number of papers	% (total number of papers = 22)
Payments	12	55%
Compliance automation tools	6	27%
Robo-advisors	3	14%
Budget management	2	9%
Other	4	18%

4.4.1 Payments and transactions

The applications in this class were being used to handle money in a digital form. This class includes sub-classes with subtle differences in definitions.

A digital wallet, also called e-wallet, is software that enables the user to store credit and debit cards in a digital form and use those cards for payments [Ken22]. Digital wallets can also store customer loyalty cards, discount coupons or event tickets. In addition to traditional currency cards, e-wallets can be used for storing and using cryptocurrencies. Popular digital wallets are, for example, Apple Pay and PayPal. Mobile wallet is a digital wallet as a mobile application that can be used with mobile phones or even wearable devices such as watches to make contactless and cashless payments [Ken22].

E-money is monetary value that is saved in electronic form and used for transactions [Fir09]. It can be saved on different platforms such as devices, cards or servers.

While mobile banking refers to traditional banks offering their services via mobile device applications, mobile money accounts are provided by mobile network operators or their

partner companies [IMF]. The only requirement for mobile money services is a mobile phone, traditional bank account is not needed.

Mobile payments, cashless payments

Hartatik et al. [HFA21] combines a cashless payment system to the smart village concept. The application called Go-Payment enables cashless transactions in the village and aims to promote tourist attractions and local commodities in an environment without banking infrastructure. The functionalities of the application include making bookings and payments. The application has both web- and mobile-based user interfaces.

Wibowo and Fahmi [WF21] have developed a mobile application for a smart vending machine. The proposed application is a cashless and contactless system for ordering and paying for purchases.

Fan et al. [Fan+18] propose in their paper a secure authentication protocol for mobile payments. With mobile payments becoming more and more popular globally, security remains a key concern. Payment technologies such as Near-Field Communication (NFC) and QR code payments remain vulnerable for fraud. An important step in the proposed protocol requires the user of a device to authenticate with the device before a transaction is conducted. The authentication ensures that only a valid user of the device can make the payment.

VoiceNote is a QR code-based mobile payment application that can be controlled with voice. In addition to the mobile application, a web application and dashboard provide additional functionalities for monetary management. It includes a budget planning feature for budget management [Has+19]

Digital wallets

Chen et al. [CJW17] describe digital Bitcoin wallets and payments. They propose a supervising system that makes it easier for the authorities to control the transactions while also providing the users transparency and convenience.

Cam-Wallet is a prototype of a mobile wallet application that can be used to store the user's identity and payment cards as well as to make payments using NFC [OB17]. The paper proposes a novel authentication method reading the user's fingerprint with the device's built-in camera. The authors state that basic authentication such as PIN code or a password is not sufficient to curb threats but biometric authentication is needed. Since not all devices are equipped with the required sensors, the device's camera can be utilized for reading the fingerprint.

Mobile money

Mesfin et al. [Mes+15] have designed a mobile money application for illiterate users. It promotes financial inclusivity by providing a way for the illiterate to use mobile money in a way that is similar to the use of real cash money. Instead of a text interface, money is represented as bills in this prototype web application running on a smartphone.

Ali et al. [ADE21] developed a prototype of a mobile money application. The focus of the study was to develop a secure and efficient multi-factor authentication algorithm to be used in mobile money applications. Mobile money is a way to promote financial inclusivity by providing ways to send and receive money for the unbanked people.

E-money

Haryadi et al. [Har+18] analyze the design of e-money and provide insight into the implementation of an e-money application for mobile phones. The primary purpose of the application is to replace cash money transactions. The application provides functionalities for purchases and cash withdrawals with QR codes.

Mobile banking

Suryatmojo et al. [Sur+18] propose a mobile banking platform that combines a user's multiple accounts from different banks and other financial institutions into one application. The application would provide the functionalities of a traditional mobile bank but with improved efficiency. A user can see all of their credit and debit funds as well as investment data summed in one place. The authors propose using Service Oriented Architecture (SOA) in the integration of different banks and other financial service providers as data sources [Sur+18].

Payment platform

Fintech payment applications use multiple different schemes depending on the service provider and the schemes are not interoperable [MK16]. In practice, a client cannot use Apple Pay if the merchant only approves Samsung Pay. Moon and Kim describe a payment mediation platform that allows payments between different schemes. They also present a proof-of-concept implementation of the platform.

Trade finance application utilizing blockchain

Ariffin and Ismail [AI19] designed and implemented a blockchain-based trade finance application. In conventional trade finance, transactions require third-party intermediaries. The process is inefficient and expensive with high banking fees. The blockchain-based

model eliminates banking fees and creates a single shared source of truth.

4.4.2 Automated tools for compliance

In order to make compliance processes and supervision more efficient, various tools have been developed or proposed for automating those processes. The studies under review presented tools for automated reporting [CS19] [Suk+17], easier supervision and auditing of digital wallets [CJW17], more efficient Know Your Customer (KYC) process [YC19] and automatic fraud detection [Cam+17] [Bal+21].

Casturi and Sunderraman [CS19] propose a reporting framework model for an investment organization. Financial institutions managing customer finances have to provide mandatory regulatory filings to authorities. Internal reporting is needed for the company's day-to-day business operations. In addition to filings to authorities, external reporting is done for the clients of the companies. These are all examples of standard reporting. Another category is early warning reporting, conducted to prevent failures and losses in financial institutions. The enterprise is using multiple different tools for reporting and the users creating reports are not always selecting the best and most efficient tool for their reporting needs. The proposed framework still enables the use of different reporting tools but the database is moved from the company's own servers to the cloud and the users are encouraged to use the most efficient tool for the current task/type of report [CS19].

A smart cooperative system designed by Sukmana et al. [Suk+17] automatically creates reports from the cooperative members' data and sends the reports to the relevant Indonesian authorities monitoring and supervising cooperatives.

Chen et. al [CJW17] demonstrates a Bitcoin collection supervision system for transparency and for simpler regulation and auditing of financial transactions. This enables, for example, easier tax collection. The developed system is intended for transactions between customers and merchandise stores who use Bitcoin digital wallets [CJW17].

Yadav and Chandak [YC19] aim to make the KYC process more efficient and improve the customer experience while reducing costs to the banks. Fulfilling the obligations for the KYC regulations is expensive for the providing banks and typically the customers have to replicate the process separately for each institution. The proposed solution utilizes blockchain technology and requires the customer to go through the verification process only once through an application. The user is then able to register as a customer to different banks using the same application [YC19].

Camino and Valtchev [Cam+17] utilize unsupervised learning methods to identify suspicious financial activity and transactions. Traditionally, software tools for fraud detection have used rulesets defined by domain experts.The drawback is that those tools can only identify known suspicious schemes. The authors propose a methodology for exploratory data analytics and present two case studies of applying the algorithms and analyzing the data [Cam+17].

Umaithanu et al. [Bal+21] propose an algorithm that embeds graphs built using transaction data and combines that data with sequence-based embeddings of customers' historical transactions. The algorithm can be used for both risk assessment and market research purposes. Fintech companies handle large volumes of transactional data that is constantly changing and growing. The authors deployed the algorithm to study PayPal data. Improving the risk assessment capability of a big corporation can save the company several millions of dollars yearly [Bal+21].

4.4.3 Budgeting tools

Smart budgeting tools help users to better understand and plan their spending and savings by automatically categorizing purchases and payments.

A smart budget manager developed by Allegue et al. [AAE21] applies machine learning, natural language understanding (NLU) and natural language processing (NLP) methods to detailed bank customers' transaction data. As a result, the customers benefit by automatically having a clear view of their categorized spending. They can also receive personalized offers from the bank. The bank can use the same data for more granulated segmentation of customers and the offers can be tailored for the spending habits of the customers [AAE21].

An automatic budget manager is also included in the voice controlled mobile and web payment application by Hashan et al. [Has+19]. It provides a web dashboard for viewing and analyzing spending behavior. The user can create a monthly budget with different categories and the application will automatically keep track of transactions and notify the user if a budget category is reaching its limit [Has+19].

4.4.4 Robo-advisors

A robo-advisor is a platform that provides investment advisory and planning service based on algorithms without human supervision. It is a cost-efficient service that uses the customer's financial situation and goals to automatically allocate the investment funds [Fra22].

Day et al. [DCL18] propose a portfolio optimization module that could be used as a sub-system of a robo-advisor. Day et al. [DLC18] have developed a conversational robo-advisor that replies to the user's queries and deployed it to different platforms, for example Facebook Messenger.

4.4.5 Other applications

Yadav and Chandak's [YC19] proposed application makes the KYC process easier for the customer. With the application, the customer needs to go through the process only once and then use the application to register with multiple service providers. The application is also classified to belong to the compliance automation category (4.4.2).

Smartcoop is a financial system for cooperatives in Indonesia [Suk+17]. The paper proposes a system design architecture for a service that can be used by cooperatives for savings, loans and financial transactions. The cooperative's transactions can also be monitored by the authorities automatically through the system [Suk+17]. The proposed system is also classified to belong to the compliance automation category (4.4.2).

CEBRA is an application for banks to recommend banking products based on customer data [Her+21]. It is a case-based reasoning system that can be included in a fog computing architecturecoordinated by virtual agents. It consists of a recommendation algorithm and a REST interface.

Zhuo et al. [ZLY20] developed an asset allocation optimization module and deployed it on a business platform. It demonstrated how to combine financial big data and technology to utilize that data in a financial system.

4.5 Fintech application development competencies

The competence classes were created using a concept mapping technique. Keywords related to technologies and skills were extracted from the reviewed literature and related

skills were grouped together to form competence areas needed in fintech software development. After mapping keywords and skills, the relevance and specificity of the competencies to fintech software development were evaluated. An illustration of the keyword map is presented in figure 3.3.

4.5.1 Software development and technology skills

The categories for software development and technology skills and the related primary studies are presented in table 4.4.

Blockchain

Blockchain is a type of distributed ledger. A recorded transaction is added as a new block to the chain and each block depends on all of the previously added blocks. It is immutable as blocks can only be added but not removed or modified [AI19].

Smart contracts work on top of a blockchain network. A smart contract is a piece of code that is executed when some predefined conditions are met. Smart contracts are immutable and the execution of a smart contract cannot be stopped once it has started [ASS19]. Bitcoin is a cryptocurrency that utilizes blockchain technology [CJW17]. Ethereum is a blockchain-based platform for smart contracts [YC19]. It is also known as a cryptocurrency. Hyperledger Fabric is also a blockchain framework [AI19].

Blockchain and its applications were the subject of five research papers as shown by technology keywords in table 4.3. Additionally, [ASS19] studied smart contracts in relation to civil code. Blockchain technology was implemented in trade finance application [AI19], KYC process [YC19], insurance processes [Rai+18], digital wallet supervision system [CJW17] and open banking system [Xu+20].

Table 4.3: Blockchain technology keywords

Keyword	Reference
Smart contract	[AI19] [YC19] [Rai+18] [Xu+20]
Hyperledger fabric (framework)	[AI19] [Rai+18]
Bitcoin	[CJW17]
Ethereum	[YC19]

Testing fintech software systems

Three papers ([Wan+18] [Jin+19] [Wan+21]) covered testing of fintech software systems.

Fintech software systems are mission critical and errors can lead to huge financial losses [Jin+19]. However, Wang et al. [Wan+18] and Jin et al. [Jin+19] argued that the fintech industry still depends heavily on manual testing in software development. Fintech software systems contain complex business logic and creating test cases requires a lot of domain knowledge [Jin+19].

The example system described in [Wan+18] contains multiple subsystems that take high-dimensional inputs with various data types and formats that can be user-defined data structures. The test value space with normal and exceptional inputs is huge and beyond the capabilities of existing testing tools. The authors develop a method for automated black-box testing that uses system logs as seeds for test inputs [Wan+18].

Continuing their earlier work [Wan+18], Jin et al. [Jin+19] identify shortcomings in lacking domain knowledge of data field dependencies and lacking domain knowledge of exceptional cases of input data. The mostly undocumented business logic and data fields contain dependencies that need domain expert knowledge to understand. They propose a system where the domain knowledge is documented and structured to enable automatic domain-specific test generation [Jin+19].

Wang et al. [Wan+21] proposed a fuzz testing framework for fintech software systems [Wan+21]. The proposed framework also takes into account external inputs such as environmental settings. It prioritizes input object fields and mutates test inputs for both object fields and environmental settings [Wan+21].

Improved line coverage in the testing of systems under research was mentioned as a result of research work in all studies [Wan+18] [Jin+19] [Wan+21] concerning testing fintech software systems.

Open banking related skills: APIs and security

With the advance of open banking and new innovative fintech services, the traditionally closed and secure computer systems containing customer data of banks have had to be made available for third parties. The communication between different systems is enabled with cross-platform and programming language neutral application programming interfaces (APIs) with common protocols. The APIs enable fintech services such as online purchases and mobile payments but the data provided through the interfaces could be used for other purposes as well, such as marketing or investment research by investigating different customer segments [Üns+20]. Thus, the APIs provide new channels for revenue for the institutions collecting the data.

Ünsal et al. [Üns+20] describe a fintech API Gateway they have developed. The main challenge in developing APIs is the security of the system with the bigger attack surface they provide for potential attackers. Strong and secure authentication process and data confidentiality are essential for the system.

For the higher authentication and provenance needs of the open banking, Xu et al. [Xu+20] propose a data sharing model that utilizes blockchain technology and programmable smart contracts. In addition to the security and privacy, the proposed model provides auditable provenance by creating a record of the user's financial data actions [Xu+20].

Security and authentication technologies

Security and authentication methods are essential to the new payment systems and digital wallets as highly sensitive data may be stored in the application. Okpara and Bekaroo [OB17], Fan et al. [Fan+18] and Ali et al. [ADE21] proposed different methods for better authentication for the users.

Cam-Wallet mobile wallet application prototype [OB17] uses the camera embedded in the mobile device to capture the user's fingerprint for authentication. Biometric authentication with capacitive fingerprint scanners have become a popular way of authentication and authorization, However, the technology is not used in lower priced devices and is out of reach of many customers. Using the device's camera would bring the methodology to a wider audience [OB17].

Fan et al. [Fan+18] propose a secure authentication protocol for mobile payments. Compared to traditional payments, mobile payments have new security issues brought by the open payment environment and new communication media. The challenges are related to the reliability of transactions and the confidentiality and integrity of data. Similarly, Ali et al. [ADE21] propose a secure multi-factor authentication algorithm for mobile money applications.

Mobile development

Fourteen studies presented a mobile fintech application. In addition to knowledge of different platforms, special mobile development skills are related to the devices' unique technologies and payment media and schemes compared to web applications. Those technologies include QR-code payments with the device's camera [HFA21] [Har+18] [Has+19] [ADE21], near-field communication (NFC) [MK16] [CJW17] [OB17] and using sensors such as camera [OB17] and microphone [Has+19]. Papers referring to mobile development as well as other technologies are listed in table 4.4.

Table 4.4: Software development skills

Competence/technology	Number of studies	References
Blockchain	5	[AI19] [YC19] [Rai+18] [Xu+20] [CJW17]
Testing	3	[Jin+19] [Wan+18] [Wan+21]
Open banking	2	[Üns+20] [Xu+20]
Security and authentication	3	[OB17] [Fan+18] [ADE21]
Mobile development	14	[MK16] [Suk+17] [Sur+18] [HFA21] [YC19] [Mes+15] [CJW17] [OB17] [WF21] [Fan+18] [Har+18] [Has+19] [ADE21] [AAE21]

4.5.2 Data science skills

Artificial Intelligence

Table 4.5 presents six fintech applications in the reviewed articles that were implemented with machine learning methods. Deep learning was used for data intensive applications predicting stock prices [DLC18], detecting fraud in transaction data [Bal+21] and optimizing investment portfolios [DCL18]. Other identified machine learning methods were case-based reasoning (CBR) for a banking product recommendation system [Her+21], unsupervised learning method for finding suspicious transactions [Cam+17], and text classification with supervised learning for a smart budget manager tool [AAE21]. The smart budget manager also applied Natural Language Understanding (NLU) and Natural Language Processing (NLP) methods.

Big Data and data mining

The charasteristics of financial big data are that it is constantly accumulating and changing [ZLY20], it is multi-dimensional and it can be structured or unstructured [Bal+21]. The collected data is analysed using data science and artificial intelligence methods. Use cases for utilizing large scale and big data in the review material were robo-advisor [DCL18], asset allocation [ZLY20], fraud detection and prediction [Bal+21] [Cam+17], and personalized service for the clients and better customer segmentation for banks [AAE21].

Table 4.5: AI methods

Method	Reference(s)
Deep Learning (ML)	[DLC18] [Bal+21] [DCL18]
Case-based reasoning (ML)	[Her+21]
Unsupervised learning (ML)	[Cam+17]
Supervised learning (ML)	[AAE21]
Natural Language Understanding (NLU)	[AAE21]
Natural Language Processing (NLP)	[AAE21]

5 Discussion

5.1 Answering the research questions

The systematic literature aimed to answer three research questions presented in chapter 1 and section 3.1 concerning software development in the fintech context. To answer the research questions, 31 research articles (table 3.2) were selected implementing a systematic process. The selected studies were categorized based on the content and keywords that were extracted during the reading process.

5.1.1 The services developed and provided by the fintech industry

To answer the first research question, "What kind of digital services are developed and provided by the fintech industry?", a subset of the review material concerning services and applications was studied as presented in section 4.4. The provided services were extracted from the papers and analyzed. The percentages of application types in categories are shown in table 4.2. The largest group of services, 55% of the applications proposed in the research papers, were applications aimed at consumers for making payments in the form of mobile and digital wallets, e-money, mobile money and mobile banking platform. The payments category also included services that would promote financial inclusivity [ADE21] and provide banking services for illiterate users [Mes+15], low-infrastructure areas such as cooperatives [Suk+17] and smart villages [HFA21]. A second significant group with 27% of the identified services consisted of tools that automated processes for compliance and were mostly aimed at corporative use.

Mobile payments category included multiple variations of means to make electronic transactions: digital wallets provide a way to store and use traditional card information in digital form, e-money is a currency that is loaded to a card or a device, and mobile money refers to monetary services provided by mobile operators or their partner companies for the owners of mobile phones. Mobile banking applications presented in the material also provided automatic tools for handling budgets.

Other types of applications were robo-advisors that provide cost-efficient services for in-

vestment planning and automated tools that make the auditing, reporting and fraud detection processes more efficient for the various internal and external reporting purposes.

5.1.2 Competencies and skills needed in fintech software development

To answer the second research question, "What software or technology related competencies and skills are needed in the production of fintech applications?", a concept map of competencies was created based on categorization of keywords identified in the material (figure 3.3). Two categories were created for the software development field and the data science field (section 4.5). These categories were further divided into subgroups.

Mobile development skills, skills in emerging technologies and data science skills were identified as the most important competencies needed in the development of fintech applications.

In the software development category (table 4.4), both competencies related to new technologies or concepts and more general software development skills were found. The former subgroup included blockchain and its different applications and open banking related knowledge in the form of developing APIs. For more general competencies, mobile development is an important skill as mobile banking and payments are a big group of fintech applications. Security related competencies as well as testing skills were also found to belong to this subgroup.

Mobile phones are main devices for new ways of making payments and transactions. NFC technology and QR codes enable fast contactless payments and the device's sensors can be used for identification and authentication. Blockchain and its applications such as smart contracts are being utilized for compliance and transparency, secure authentication and digital currencies.

Data related competencies were labeled under the data science category. Financial transactions create a large amount of constantly evolving customer data. Data science skills are needed in the aggregation and analysis of data.

The subgroups for this category were big data and artificial intelligence. Handling large volumes of constantly evolving data, aggregating and analyzing the data and data mining were found to be competencies in need. Skills in artificial intelligence methods such as machine learning are utilized for handling the data for many purposes from stock market

predictions to fraud detection.

5.1.3 Fintech software requirements

Fifteen of the 31 primary studies (table 3.2) mentioned one or more non-functional requirements of a fintech application (table 4.1). These fifteen papers were analyzed to answer the third research question, "What special requirements need to be considered in fintech software development?" (section 4.2). The most mentioned requirement was security with eight mentions in the fifteen papers (53%). Related to security, privacy was also mentioned in four articles. Financial data is highly sensitive and must be protected. Financial sector is highly regulated with local and international laws and compliance was mentioned in five papers. Reliability (three mentions) and availability (two mentions) are natural requirements for fintech applications, given that such systems are mission critical for businesses and disruptions of services can lead to huge losses [Jin+19].

The most important non-functional requirement for fintech systems is security. The systems store and handle sensitive data that must remain confidential and data protection is required by laws such as the GDPR. Strong authentication algorithms are needed to protect different parts of the systems from fraudulent activity. The systems must also be available and reliable. The customers expect the services to be available all of the time and unreliable service could lead to reputational and operational losses. Fintech applications are business critical and errors can lead to big reputational and monetarial losses and cause liability issues for the companies.

Fintech software has many special domain requirements that were presented in section 4.3. Anti-money laundering and anti-terrorism laws require financial companies to monitor transactions [Deg19] and verify the identity of their customers [Cam+17] [YC19]. Privacy laws such as the GDPR play an important role in data protection. International companies must comply with the laws of several countries [Deg19]. Regular reporting and auditing are required of the companies.

Fintech software development requires strong domain knowledge. The field is regulated by different laws and the business logic of large systems is very complex. The emerging technologies create new needs for regulation and ways of applying the already existing laws. The three studies [Wan+18] [Jin+19] [Wan+21] in the material concerning testing fintech software systems underlined the complexity and the importance of cooperation with the domain experts and developers.

5.2 Key findings and observations

We found that the majority of the consumer fintech applications are payment services and digital wallets while the services provided for financial institutions aim at more efficient business processes through automation. Financial data is vital for fintech services as collecting, processing and analyzing financial data and transactions enable the development of personalized services and robo-advisors for customers while artificial intelligence tools can also be used for fraud detection and stock market prediction.

In fintech software development, mobile development skills already are and will remain essential since consumers have become accustomed to the ubiquitousness of the devices and the availability of services regardless of time and place. Data science skills for handling the growing amount of financial data will also be needed more and more as new data sources emerge. New services could be built on, for example, data harvested from sources in the Internet of Things and social media accounts. Cyber security competencies will also be needed as security is the most important requirement for a fintech software system.

The definition of fintech is still not well established and several other closely related terms are being used variably with fintech. As discussed in chapter 2, subfields such as RegTech, SupTech and InsurTech that in earlier research articles are considered as fintech are more recently being considered as their own areas of technology. In this thesis, the automated compliance and supervision processes were qualified as fintech although those could also be categorized as RegTech or SupTech applications being used in fintech systems. Decentralized finance (DeFi) is also a field that some consider not to be part of fintech but in this review blockchain applications such as cryptocurrencies were considered as fintech.

The results of this review considering the applications and services provided in the fintech field are in line with previous studies used as the references while formulating the research questions. Paul and Sadath's systematic analysis of fintech applications [PS21] identified blockchain, mobile payments, open banking, robo-advisors, InsurTech and RegTech as the most active fields of fintech. [PS21] and [DS19] discussed also fintech's ability to promote financial inclusion by bringing banking services to the low-infrastructure areas and for people who have previously been unable to get those services.

5.3 Limitations and threats to validity

Fintech is a multidisciplinary field and during the initial exploratory queries it became obvious that limiting the search with a too specific search string would yield only a very limited number of primary studies as a result. It also became obvious that not much research concerning software development in particular in the fintech field has yet been done. A decision was made to search with a short and permissive query string and limit the query further with other filters. In the Scopus database search, only Computer Science and Engineering topic areas were selected. This may have resulted in some potentially relevant studies not being found.

During the elimination rounds of the review process a decision was made to exclude studies about prediction and fraud detection algorithms without a concrete example application. A total of 30 studies were eliminated on that basis. That seems to be an active area of research even though it was left out of the scope of this study. Another decision limiting the number of studies included in the final selection was the decision to exclude usability or user experience studies and user acceptance and perception studies about fintech applications and systems. A total of 36 studies were eliminated on that basis in the process, although human computer interaction studies are arguably an important part of software development. After the analysis of the selected studies these eliminated papers were inspected again and it was concluded that the inclusion would not bring any new information about the research questions.

5.4 Implications and further research

Fintech solutions are critical also for systems outside of the financial services industry. For example, the identification services that are provided by banks in Finland are being used for identifying the user in many contexts. Fintech companies use the service for authenticating payments while other services and government institutions require using it for online services. Disruptions in the applications or underlying systems have a massive impact on daily life. The downsizing of in-person services in banks have in part forced customers to use online banking services. Card and mobile payments are replacing cash in stores. When these critical systems are not available due to system failures or updates, transactions cannot be made.

Fintech software industry and its services are based on sharing data and functions through

open banking APIs, gathering, storing and utilizing data, and applications running on mobile devices. All of these need skilled software engineers, developers and data scientists. Security and cloud engineers are in demand to design secure distributed systems as few companies manage their own infrastructure and cloud environment provides cost efficient scalability. Combining development, security and operations (DevSecOps) skills ensures that applications and systems are produced in an agile manner without sacrificing security.

As services such as handling payment transactions and identification can be considered critical, disruptions of these services can cause financial losses and even damage to the society by crippling the essential functions. The future research on the field could be related to cyber security and the prevention of disruptions in the critical infrastructure. Also, while issues can arise as a result of malicious activity and attacks, even basic maintenance and updates of the systems have caused interruptions in service. System architectures and designing for availability would be interesting directions in research of fintech.

While going through the review process, it was noted that research about fintech software requirements was quite sparse. Requirements related to regulations were covered in many papers but no papers were found about requirements engineering specifically in the fintech field, and even papers about applications did not cover the non-functional requirements well. This may implicate that requirements engineering in fintech software development is not considered to be a separate field or different from other industries. Security and privacy are obviously essential requirements in fintech, as well as high availability and reliability.

Although user studies were excluded from this review, good usability and accessibility of customer facing applications is also vital. While one benefit and goal of fintech is to promote financial inclusivity, the digitalization of critical services can also exclude some demographic groups and make the services unavailable to them. Accessibility of the services is a requirement that was not mentioned in the review material. The European Accessibility Act requires that important services including banking are accessible and available for all. The law applies to both devices and applications. To be able to use a digital service, a person has to have a suitable device and skills to use it. Even in the developed world, a large portion of the elderly are lacking both. Accessibility of fintech software needs also to be considered in the future software engineering research.

6 Conclusions

Fintech is an industry that applies technology to provide innovative financial services that compete with and complement existing ones. The enablers for fintech companies have been the advances in technology and recent changes in regulations that have forced traditional financial institutions such as banks to open up their customer databases to third parties.

The aim of the current study was to find out what kind of services are provided by the fintech industry and what kind of requirements are characteristic to fintech software systems. An additional goal was to find out what kind of software competencies and skills are needed in the fintech industry. To answer these research questions, a systematic literature review was conducted based on the suggested method by Kitchenham [Kit04]. After conducting queries in three scientific databases and comparing the results of the queries to a decided inclusion and exclusion criteria, 31 primary studies were selected as the material for the study.

The systematic literature review material covered multiple topics. The majority of the studies presented an application or an architecture of a software system. Two studies were about the legal aspects and regulations of the financial sector. Three studies described algorithms and their implementations in fintech software systems.

The largest group of applications found in the selected primary studies were related to payments with mobile devices. Using the ubiquitous mobile phone is a convenient way to handle transactions. It also enables bringing banking services to previously unbanked people, thus promoting financial inclusivity. With mobile devices being an important enabler of fintech, mobile development skills are a key competency area required in the development of services. Another main area of needed competencies is data science skills. Financial industry creates vast amounts of data and smart utilization and aggregation of that data requires skills in artificial intelligence and big data.

Developing fintech software systems requires strong domain knowledge. The financial services industry is heavily regulated and fintech companies must comply with all regulations. Security is the most important requirement of fintech services to protect sensitive data and avoid monetary losses. Emerging technologies such as blockchain based cryptocurrencies create a need to review current laws in relation to new innovations.

Fintech applications such as digital payment and mobile banking tools have become a part of daily life. For financial institutions, automating processes such as accounting and regulatory compliance audits brings improved efficiency and savings. Fintech applications also enable other digital services including e-commerce websites and transaction platforms such as Über and Airbnb. New technologies for collecting and processing data are characterizing the current phase of digitalization of the financial services industry and creating opportunities for innovating new services. As a software development research topic area, fintech offers various important research topics in the future, ranging from fintech infrastructure to algorithms.

Bibliography

[AAE21] S. Allegue, T. Abdellatif, and H. El Abed. "SBM: A Smart Budget Manager in banking using machine learning, NLP, and NLU". In: *Concurrency and Computation: Practice and Experience* (2021).

[ADE21] G. Ali, M. A. Dida, and A. Elikana Sam. "A Secure and Efficient Multi-Factor Authentication Algorithm for Mobile Money Applications". In: *Future Internet* 13.12 (2021).

[AI19] N. Ariffin and A. Z. Ismail. "The Design and Implementation of Trade Finance Application based on Hyperledger Fabric Permissioned Blockchain Platform". In: *2019 International Seminar on Research of Information Technology and Intelligent Systems (ISRITI)*. 2019, pp. 488–493.

[ASS19] M. di Angelo, A. Soare, and G. Salzer. "Smart Contracts in View of the Civil Code". In: *Proceedings of the 34th ACM/SIGAPP Symposium on Applied Computing*. SAC '19. Limassol, Cyprus: Association for Computing Machinery, 2019, pp. 392–399.

[Bal+21] M. Balan Umaithanu, V. Ravichandran, M. Rohith Srinivaas, and V. Subramanian Selvaraj. "DeepGRASS: Graph, Sequence and Scaled Embeddings on large scale transactions data". In: *2021 Swedish Workshop on Data Science (SweDS)*. 2021, pp. 1–6.

[But20] T. Butler. "What's Next in the Digital Transformation of Financial Industry?" In: *IT Professional* 22.1 (2020), pp. 29–33.

[Cam+17] R. Camino, R. State, L. Montero, and P. Valtchev. "Finding suspicious activities in financial transactions and distributed ledgers". In: vol. 2017-November. 2017, pp. 787–796.

[CJW17] P.-W. Chen, B.-S. Jiang, and C.-H. Wang. "Blockchain-based payment collection supervision system using pervasive Bitcoin digital wallet". In: *2017 IEEE 13th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)*. 2017, pp. 139–146.

[CS19] R. Casturi and R. Sunderraman. “Enterprise Framework for Business Intelligence Tools on Cloud Computing Environment for Investment Platforms”. In: *Proceedings of the 9th International Conference on Information Systems and Technologies*. icist 2019. Cairo, Egypt: Association for Computing Machinery, 2019.

[DCL18] M.-Y. Day, T.-K. Cheng, and J.-G. Li. “AI Robo-Advisor with Big Data Analytics for Financial Services”. In: *2018 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM)*. 2018, pp. 1027–1031.

[Deg19] K. Degerli. “Regulatory Challenges and Solutions for Fintech in Turkey”. In: vol. 158. 2019, pp. 929–937.

[DLC18] M.-Y. Day, J.-T. Lin, and Y.-C. Chen. “Artificial Intelligence for Conversational Robo-Advisor”. In: *Proceedings of the 2018 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining*. ASONAM ’18. Barcelona, Spain: IEEE Press, 2018, pp. 1057–1064.

[DS19] E. Davradakis and R. Santos. *Blockchain, FinTechs and their relevance for international financial institutions*. Tech. rep. EIB Working Papers, 2019.

[Fan+18] K. Fan, H. Li, W. Jiang, C. Xiao, and Y. Yang. “Secure Authentication Protocol for Mobile Payment”. In: *Tsinghua Science and Technology* 23.5 (2018), pp. 610–620.

[Fey+21] E. Feyen, J. Frost, L. Gambacorta, H. Natarajan, M. Saal, et al. “Fintech and the digital transformation of financial services: implications for market structure and public policy”. In: *BIS Papers* (2021).

[Fir09] J. Firpo. *E-Money – Mobile Money – Mobile Banking – What’s the Difference?* 2009. URL: https://blogs.worldbank.org/psd/e-money-mobile-money-mobile-banking-what-s-the-difference (visited on 05/20/2022).

[Fra22] J. Frankenfield. *Mobile Wallet*. 2022. URL: https://www.investopedia.com/terms/r/roboadvisor-roboadviser.asp (visited on 05/20/2022).

[Gec+14] D. Gechevski, K. Poposka, B. Angelova, and V. Gecevska. “Agile software development products for fintech - Financial Technologies”. In: *Proceedings of the 8th International Conference on Mass Customization and Personalization*. Vol. 23. 6. 2014, pp. 107–113.

[Har+18] D. Haryadi, Harisno, V. H. Kusumawardhana, and H. L. H. S. Warnars. "The Implementation of E-money in Mobile Phone: A Case Study at PT Bank KEB Hana". In: *2018 Indonesian Association for Pattern Recognition International Conference (INAPR)*. 2018, pp. 202–206.

[Has+19] B. Hashan, Y. Abeyrathna, M. Kaluaratchi, A. Piyalath, and S. Thelijjagoda. "VoiceNote: An Intelligent tool for monetary transactions with integrated voice support". In: *2019 International Research Conference on Smart Computing and Systems Engineering (SCSE)*. 2019, pp. 119–125.

[Her+21] E. Hernández-Nieves, G. Hernández, A. Gil-González, S. Rodríguez-González, and J. Corchado. "CEBRA: A CasE-Based Reasoning Application to recommend banking products". In: *Engineering Applications of Artificial Intelligence* 104 (2021).

[HFA21] Hartatik, N. Firdaus, and A. Aziz. "Go-Payment: Towards Cashless Payment System for Smart Village Application in Indonesia". In: *2021 3rd International Conference on Cybernetics and Intelligent System (ICORIS)*. 2021, pp. 1–6.

[IMF] IMF. *FAS: What is mobile money? How is it different from mobile banking?* URL: https://datahelp.imf.org/knowledgebase/articles/1906552-fas-what-is-mobile-money-how-is-it-different-fro (visited on 05/20/2022).

[Jin+19] T. Jin, Q. Wang, L. Xu, C. Pan, L. Dou, H. Qian, L. He, and T. Xie. "FinExpert: Domain-Specific Test Generation for FinTech Systems". In: *Proceedings of the 2019 27th ACM Joint Meeting on European Software Engineering Conference and Symposium on the Foundations of Software Engineering*. ESEC/FSE 2019. Tallinn, Estonia: Association for Computing Machinery, 2019, pp. 853–862.

[KC07] B. A. Kitchenham and S. Charters. *Guidelines for performing Systematic Literature Reviews in Software Engineering*. Tech. rep. EBSE 2007-001. Keele University and Durham University Joint Report, July 2007.

[Ken22] W. Kenton. *Mobile Wallet*. 2022. URL: https://www.investopedia.com/terms/m/mobile-wallet.asp (visited on 05/20/2022).

[Kil+19] E. Kilu, F. Milani, E. Scott, and D. Pfahl. "Agile software process improvement by learning from financial and fintech companies: LHV bank case study". In: *International Conference on Software Quality*. Springer. 2019, pp. 57–69.

[Kit04] B. Kitchenham. “Procedures for Performing Systematic Reviews”. In: *Keele, UK, Keele Univ.* 33 (Aug. 2004).

[LS18] K. Leong and A. Sung. “FinTech (Financial Technology): What is It and How toUse Technologies to Create Business Value in FintechWay?” In: *International journal of innovation, management and technology* (Jan. 2018), pp. 74–78.

[Mes+15] W. Mesfin, T.-M. Grønli, G. Ghinea, and M. Younas. “A Mobile Money Solution for Illiterate Users”. In: *2015 IEEE International Conference on Mobile Services*. 2015, pp. 328–335.

[MHB15] C. Matt, T. Hess, and A. Benlian. “Digital Transformation Strategies”. In: *Business & Information Systems Engineering* 57.5 (2015), p. 339.

[MK16] W. Y. Moon and S. D. Kim. “A Payment Mediation Platform for heterogeneous FinTech schemes”. In: *2016 IEEE Advanced Information Management, Communicates, Electronic and Automation Control Conference (IMCEC)*. 2016, pp. 511–516.

[Nen17] H. Neng. “Construction of High-Availability Bank System in Virtualized Environments”. In: *2017 IEEE Second International Conference on Data Science in Cyberspace (DSC)*. 2017, pp. 561–568.

[OB17] O. S. Okpara and G. Bekaroo. “Cam-Wallet: Fingerprint-based authentication in M-wallets using embedded cameras”. In: *2017 IEEE International Conference on Environment and Electrical Engineering and 2017 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I CPS Europe)*. 2017, pp. 1–5.

[PS21] L. R. Paul and L. Sadath. “A Systematic Analysis on FinTech and Its Applications”. In: *2021 International Conference on Innovative Practices in Technology and Management (ICIPTM)* (2021), pp. 131–136.

[Rai+18] M. Raikwar, S. Mazumdar, S. Ruj, S. Sen Gupta, A. Chattopadhyay, and K.-Y. Lam. “A Blockchain Framework for Insurance Processes”. In: *2018 9th IFIP International Conference on New Technologies, Mobility and Security (NTMS)*. 2018, pp. 1–4.

[Sch16] P. Schueffel. “Taming the Beast: A Scientific Definition of Fintech”. In: *Journal of Innovation Management* 4 (Dec. 2016), pp. 32–54.

[Suk+17] A. Sukmana, Mihuandayani, Y. K. Sari, F. Hasan, A. S. E. Fathin, K. Nisa, and E. Utami. "Design concepts smartcoop with implementing financial technology". In: *2017 5th International Conference on Cyber and IT Service Management (CITSM)*. 2017, pp. 1–5.

[Sur+18] A. Suryatmojo, E. R. Kaburuan, A. N. Fajar, S. Sutarty, and A. S. Girsang. "Financial Technology Integration Based on Service Oriented Architecture". In: *2018 International Conference on Orange Technologies (ICOT)*. 2018, pp. 1–5.

[Üns+20] E. Ünsal, B. Öztekin, M. Çavuş, and S. Özdemir. "Building a Fintech Ecosystem: Design and Development of a Fintech API Gateway". In: *2020 International Symposium on Networks, Computers and Communications (ISNCC)*. 2020, pp. 1–5.

[Via19] G. Vial. "Understanding digital transformation: A review and a research agenda". In: *The Journal of Strategic Information Systems* 28.2 (2019), pp. 118–144. ISSN: 0963-8687.

[Wan+18] Q. Wang, L. Gu, M. Xue, L. Xu, W. Niu, L. Dou, L. He, and T. Xie. "FACTS: Automated Black-Box Testing of FinTech Systems". In: *Proceedings of the 2018 26th ACM Joint Meeting on European Software Engineering Conference and Symposium on the Foundations of Software Engineering*. ESEC/FSE 2018. Lake Buena Vista, FL, USA: Association for Computing Machinery, 2018, pp. 839–844.

[Wan+21] Q. Wang, L. Xu, J. Xiao, Q. Guo, H. Zhang, L. Dou, L. He, and T. Xie. "FinFuzzer: One Step Further in Fuzzing Fintech Systems". In: *2021 36th IEEE/ACM International Conference on Automated Software Engineering (ASE)*. 2021, pp. 1111–1115.

[WF21] D. Wibowo and F. Fahmi. "Contactless and Cashless Smart Vending Machine Integrated with Mobile Device". In: *2021 5th International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM)*. Vol. 5. 2021, pp. 146–151.

[Xu+20] Z. Xu, Q. Wang, Z. Wang, D. Liu, S. Wen, and R. Hanson. "PPM: A Provenance-Provided Data Sharing Model for Open Banking via Blockchain". In: 2020.

[YC19] P. Yadav and R. Chandak. “Transforming the Know Your Customer (KYC) Process using Blockchain”. In: *2019 International Conference on Advances in Computing, Communication and Control (ICAC3)*. 2019, pp. 1–5.

[ZLY20] J. Zhuo, X. Li, and C. Yu. “How to integrate financial big data and fintech in a real application in banks: A case of the modeling of asset allocation for products based on data”. In: *Information (Switzerland)* 11.10 (2020), pp. 1–15.