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A Concept for Smart City Data Marketplace using Enterprise Architecture and Service Design Approaches

Master's thesis in Informatics
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Abstract

Data has been called the new oil and with today's abundance of data, new challenges and opportunities arise. The growing number of smart cities generate many types of data from different domains, with both private and commercial data owners. Internet of Things (IoT) sensors, social media and other systems generate enormous amounts of data and the majority of it is not utilized. The smart city data has the potential to aid stakeholders and enterprises with decision making, improving user experiences and increasing revenues through leveraging on the data. This data can create new value-adding services which in turn could improve the lives of the citizens. To make this possible there is a need for easy sharing, trading and utilization of the data, which gives rise to the concept of a smart city data marketplace.

The main focus of this research is to design a smart city data marketplace and adopt enterprise architecture (EA) modeling and customer journeys to plan and design an example of how such a platform could look like. Therefore, there is a need to identify how EA and service design approaches can be employed to support data marketplaces. Furthermore, the study investigates what a data marketplace is and the main challenges and trends in the data trading landscape. It also explores if there is a need for a data marketplace for smart cities like Trondheim and what is needed in such a platform. The project investigates how EA modeling and service design can support the planning and design of a data marketplace. It used an agile approach with four system design iterations.

The project contributes with extended research on the data marketplace and EA domain with a focus on smart cities. The researcher was not able to find any data marketplaces for Trondheim. The main contributions are the design of the smart city data marketplace, the proposed prototype, the proposed EA model and the method of using EA modeling and service design approaches for designing the data marketplace. Furthermore, the thesis proposes definitions of a data marketplace and a smart city data marketplace, since there are currently no widely used definitions in academic papers.

Key Words: data marketplace, data trading, smart city, decentralized platforms, smart contract, Enterprise Architecture modeling, Customer Journeys, Service Design

Sammendrag

Data har blitt kalt den nye oljen og dagens overflod av data skaper både nye utfordringer og muligheter. Antallet smarte byer vokser raskt og de genererer mange typer data fra ulike domener, og har både private og kommersielle eiere. Tingenes internettsensorer (IoT), sosiale medier og andre systemer genererer enorme mengder data og mesteparten blir ikke benyttet. Data fra smarte byer har potensiale til å hjelpe interessenter og bedrifter med beslutningstaking, forbedring av brukeropplevelser og økning av inntekter ved å utnytte dataene. Dette kan bli brukt til å generere nye verdiskapende tjenester som kan forbedre livene til innbyggerne. For å kunne gjøre dette mulig trenger man enkel deling, handel og utnyttelse av data, og dette gir rom for konseptet smartby datamarkedsplass.

Hovedfokuset for dette forskningsprosjektet er å designe en smartby datamarkedsplass og benytte virksomhetsarkitekturmodellering (EA) og kundereiser, for å planlegge og designe et eksempel på hvordan en slik plattform kan se ut. Det er derfor behov for å identifisere hvordan EA-modellering og tjenestedesign kan brukes til å støtte datamarkedsplasser. Videre undersøker studien hva en datamarkedsplass er og de viktigste utfordringene og trendene innenfor datahandel. Prosjektet utforsker også om det er behov for en datamarkedsplass for smarte byer slik som Trondheim, og hva som trengs i en slik plattform. Det blir også undersøkt hvordan EA-modellering og tjenestedesign kan støtte planleggingen og utformingen av en datamarkedsplass. Prosjektet har brukt en smidig metodikk med fire iterasjoner med systemdesign.

Forskningsprosjektet bidrar med utvidet forskning på datamarkedsplass- og EA-modelleringsdomenet med fokus på smarte byer. Studien av eksisterende datamarkedsplasser fant ingen datamarkedsplass for Trondheim. De viktigste bidragene fra prosjektet er utformingen av smartby datamarkedsplassen, den foreslåtte prototypen, EA-modellen og kombineringen av EA-modellering og tjenestedesign for å designe en datamarkedsplass. Videre foreslår oppgaven definisjoner av en datamarkedsplass og en smartby datamarkedsplass, ettersom det ikke eksisterer noen klare definisjoner i akademisk litteratur.

Nøkkelord: datamarkedsplass, datahandel, smarte byer, desentraliserte platformer, smarte kontrakter, virksomhetsarkitektur modellering, brukerreiser, tjenestedesign

Acknowledgment

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Acronyms

API Application Programming Interface. 16

DApps decentralized applications. 19

EA Enterprise Architecture. iii

IDI Department of Computer Science. v

IDS-RAM Industrial Data Space Reference Architecture Model. 21

IoT Internet of Things. iii, iv, 132

NTNU Norwegian University of Science and Technology. v

TAM Technology acceptance methods. 34

TOGAF The Open Group Architecture Framework. 21

Chapter 1

Introduction

This chapter includes the problem statement, the motivation, the context and scope, the research questions, the research objectives, the research methods, the contributions and the report outline.

1.1 Problem Statement

The amount of global data reached 59 zettabytes of data in 2020 and is expected to reach 149 ZB by 2024 according to Statista.com [1]. With the abundance of data, new challenges and opportunities arise. Internet of Things (IoT), sensors, social media and other systems generate enormous amounts of data and the majority of it is not utilised. The data has potential to aid stakeholders and enterprises with decision making, improving user experiences and increase revenues through leveraging on the data. To make this possible there is a need for easy sharing and trading of the available data. This gives rise to the concept of a smart city data marketplace. The concept of an open data marketplace has been discussed in the context of smart cities. In a complex environment, such as a city, there are many challenges and opportunities where an open data marketplace could support cities to provide value-added services to the citizens. There exist many challenges related to the concept of data marketplaces and they are concerning security, data quality, trust, data ownership and pricing models [2] [3].

This research proposes enterprise architecture modeling (EA) as a means of describing all the crucial components of a data marketplace for smart cities. The EA modeling concept can be used to identify the stakeholders, data owners, prosumers, data formats, technologies and other relevant information for the data marketplace. The main focus of this research is to design a smart city data marketplace and adopt EA modeling and customer journeys to plan and design an example of how such a platform could look like. Therefore, there is a need to identify how EA and service design approaches can be employed to support data marketplaces.

1.2 Motivation

The researcher was not able to find any current data marketplaces for Trondheim, and this project will use Trondheim as an example. Today there are no academic studies that explores what is needed in a data marketplace for Norwegian smart cities and if there is a need for such a platform in Norway and specifically Trondheim. This research project aims to investigate the needs, challenges and requirements for such a data marketplace. There are no prior research on EA modeling of data marketplaces, and the project is motivated by providing research in this area and help fill the identified research gap. Additionally, the literature review findings show that there are no clear definitions of a data marketplace that are widely used, despite the large amount of academic papers on the topic [2]. Therefore the motivation is also to propose a new definition of a data marketplace that can be used in future academic papers.

The potential beneficiaries of the study are stakeholders who are developing a data marketplace for Trondheim or other smart cities. They can use the proposed EA model, customer journeys and prototype as a blueprint to better understand the concept of a smart city data marketplace and get inspirations for developing new data marketplaces.

1.3 Context and Scope

The research project will be related to the work done in Work package 1, Task 1.1 in the European +CityxChange project, which is related to Smart City EA[4]. This project is a collaboration between seven European smart cities. The goal of the project is to model systems in the smart cities and provide EA models that can work as a blueprint of the applications. This master's thesis will contribute to the +CityxChange project with a EA model and prototype of a new data marketplace specialized for smart cities that can potentially help cities become smarter.

The scope of the research project was narrowed down from exploring general data marketplaces to focus on data marketplaces for smart cities, and uses the Norwegian smart city Trondheim as an example.

The supervisors of this master's thesis, Sobah Abbas Petersen and Anthony Junior Bokolo worked with Trondheim Municipality as a customer in the +CityxChange project. During this project they identified the need for a data marketplace for Trondheim. This gave rise to the vision of a data marketplace for the smart city Trondheim which is the example city of this master's thesis.

The scope of the work of this master's thesis consisted of the following four phases:

1. The first phase was the discovery phase were there was conducted a literature review of the concepts data marketplace, smart city data marketplace and EA modeling of data marketplaces to identify a potential research gap and define research questions.

2. The second phase was the define phase where the findings from phase one was used to define personas, the functional and non-functional requirements of the data marketplace and develop customer journeys and EA model of the smart city data marketplace.
3. The third phase was the iterative design phase where the prototype of the smart city data marketplace was designed, user tested and evaluated by experts in four iterations.
4. The fourth phase was the analysis phase were the results from the findings were analysed and discussed and the final design iteration and proposed prototype and total list of requirements were delivered.

1.4 Research Questions

The research questions are defined as follows:

- **RQ1:** What is a data marketplace and what are the main challenges and trends in the data marketplace landscape?

- **RQ2:** Is there a need for a data marketplace for smart cities like Trondheim and what is needed in such a platform?

- **RQ3:** How can EA modeling and customer journeys support the planning and design of a data marketplace?

1.5 Research Objectives

The research objectives of this study include the following:

- **RO1:** To conduct a literature review of data marketplaces and EA modeling of data marketplaces. To explore relevant approaches, technologies and solutions, open data models, standards, challenges and trends for data marketplaces.
- **RO2:** To explore existing smart city data marketplaces, specify requirements and develop personas, customer journeys and EA model of the new proposed data marketplace. Furthermore, to plan and design a prototype for the smart city data marketplace based on literature findings, specified requirements, customer journeys and EA model. To conduct user testing and expert evaluation sessions to evaluate the prototype, provide feedback, suggestions for improvements and evaluate the need for a data marketplace in smart cities like Trondheim.
- **RO3:** To evaluate the use of EA modeling and customer journeys approaches to support the planning and design of a smart city data marketplace.

1.6   Research Methods

The research methods that were used in the project were literature review and semi-structured expert evaluation interviews. The research used an agile approach with four system design iterations. The EA modeling approach and service design approaches such as personas and customer journeys were used to plan and design the data marketplace. In each iteration there were conducted evaluations of the designed prototype. In addition, there were conducted evaluations of the EA modeling and customer journeys approaches for supporting the planning and design of a data marketplace.

1.7   Contributions

The master's thesis contributes with more research results related to the study areas smart city data marketplaces, EA modeling and Service design of data marketplaces. The main contributions of the master's thesis are as follows:

1. The design of the smart city data marketplace
2. The proposed smart city data marketplace Figma prototype
3. The design method of using EA modeling and Service design approaches for designing the smart city data marketplace
4. The EA model of the smart city data marketplace
5. The proposed definitions of a data marketplace and smart city data marketplace

1.8   Report Outline

The thesis is structured in 10 chapters. The first three chapters are introductory chapters and include the introduction, literature review and methodology. The next four chapters show the four system design iterations of the proposed smart city data marketplace. The iterations of the prototype follow the four phases described in Section 1.3 and each iteration is described in a separate chapter (4-7). The last three chapters include results, discussions and conclusions of the research project.

Chapter 1 "Introduction" describes the problem statement, the motivation, the context and scope, the research questions, the research objectives, the research methods, the contributions and the report outline.

Chapter 2 "Literature Review" describes the literature review methodology, the overview of the study area, the review of current practices, the related prior studies, the background study of existing platforms, the synthesis of the literature review and the updated research questions.

Chapter 3 "Methodology" describes the research design, the research approach, the research methodology and the data analysis methods.

Chapter 4 "System Design: First Iteration" describes the defined personas, the requirement specifications, the Service Design with defined customer journeys and the EA model, the prototype design, the evaluations with user testing of the prototype and evaluations of the EA modeling approach.

Chapter 5 "System Design: Second Iteration" describes the updated personas, requirement specifications, the Service Design with updated customer journeys and the updated EA model, the prototype design, the evaluations with user testing of the prototype and evaluations of the EA modeling approach.

Chapter 6 "System Design: Third Iteration" describes the updated requirement specifications, the Service Design with updated customer journeys and the updated EA model, the prototype design, the evaluations with expert evaluations of the prototype and evaluations of the EA modeling and customer journeys approaches.

Chapter 7 "System Design: Fourth Iteration" describes the updated requirement specifications, the Service Design with updated customer journeys and the updated EA model, the prototype design, the evaluations with expert evaluations of the prototype and evaluations of the EA modeling and customer journeys approaches.

Chapter 8 "Final Evaluation and Results" describes the participants of the evaluations, including their demographics and prior knowledge level of relevant topics, the proposed definition of a data marketplace, the final evaluation results, the results from the expert evaluations sessions, the total list of requirements for the smart city data marketplace, the results from the evaluation of using the EA modeling and customer journeys approaches and the proposed EA model of the smart city data marketplace.

Chapter 9 "Discussion" describes the discussion of the results including the novelty of the prototype, how the findings help answer the research questions, UN sustainability goals and lessons learned.

Chapter 10 "Conclusion" describes the summary of the thesis, the contributions and implications of the study, the limitations and the future works.

1.9   Summary

The chapter has shown the problem statement, the motivation, the context and scope of the research project, the research questions, the research objectives, the research methods, the contributions and the report outline.

Chapter 2

Literature Review

This chapter includes the literature review methodology, the overview of the data marketplaces study area, the review of current practices, the related prior studies, the background study of existing platforms, the synthesis of the literature review and the updated research questions.

2.1 Literature Review Methodology

This section includes the search strategy, data sources and inclusion and exclusion criteria for the literature review.

What: The literature review method involves reviewing existing related literature [5].

How: The method included review of related prior papers, review of current practices for data marketplaces and EA modeling and background study of existing data marketplaces. The literature review was inspired by the systematic literature review by using a search strategy, inclusion and exclusion criteria and systematically tracking the search results and findings in the GradCoach excel template[6]. Some of the fields in the template were updated to better fit the project.

Why: The method was chosen since the review of prior related literature provided an overview and in-depth knowledge about the data marketplace and EA modeling domain. The literature review helped to identify a research gap and define relevant research questions and requirements for the data marketplace. The findings helped identify the different challenges, trends, approaches and technologies in the data trading domain. Furthermore, the literature review helped evaluate and select the most suitable approaches and aspects for the new smart city data marketplace. It also included a background study of existing platforms, since it was beneficial for exploring and directly evaluating the design choices of existing data marketplaces.

Since the project did not have any customer or predefined requirements, it was extra important to conduct a thorough literature review. This helped to get a better understanding of the topic and make literature grounded decisions for requirement specifications, prototype design and methodology choices. The project

used literature review through all the stages of the research. This was done since it was important to return to literature to clarify details and explore alternative approaches for the new data marketplace.

2.1.1 Search Strategy and Data Sources

The papers were retrieved from the online databases Google Scholar, Scopus, Oria, Science Direct, IEEE and Springer. Google scholar was chosen since it has a wide range of data sources that covers relevant document types for data marketplaces and EA modeling. For instance Google Scholar include both Google patent papers, master thesis reports and technical reports, in addition to journals and conference proceedings. IEEE and ScienceDirect were chosen since their papers are peer reviewed and cover the technology and computer science categories which are relevant for the data marketplace domain.

The literature review search was conducted in September, October and November 2020, and January, February, March 2021. There was a need to continuously review and revisit papers for developing the EA models, customer journeys and prototype. Therefore the literature review was a part of the whole iterative process to find more details and better justify the design choices. Table 2.1 shows the search strategy for the literature review and shows the databases and search terms that were used. The logic operator AND was used to find papers that include several search terms such as "Data marketplace AND Smart Cities".

Table 2.1: Search Strategy

Database	Search Terms
Google Scholar, Scopus, Oria	"Data markets", "Data marketplace", "Data marketplace definitions", "Data marketplace AND Smart Cities ", "Data Marketplace AND Norway" "Data Marketplace AND Enterprise Architecture", "Enterprise Architecture Modeling AND Data Marketplaces", "Enterprise Architecture for smart cities", "Enterprise Architecture AND smart cities"
Science Direct, IEEE, Springer	"Data Marketplace", "Data Marketplace AND Smart Cities", "Enterprise Architecture Modeling AND Data Marketplaces"

Initially the search term "Data market" was used. The term was suggested by the supervisors at the start of the project and was later dropped as it was not widely used in the relevant literature.

Further the search term "Data marketplace" was used, and this provided many relevant conference proceedings, patents papers, master's thesis reports and book chapters about data marketplaces. Next the scope was narrowed down by using the search term "Data marketplace for smart cities". Naturally this provided many

duplicates with the "Data marketplace" search term, but it helped select the papers that was related to smart cities.

The search terms "Data marketplace" and "Data marketplace for smart cities" showed very few papers from Norway. Therefore "Data marketplace AND Norway" was the next search term, and the results showed that there does not exist many papers on the Data marketplace topic from Norway besides the Prodatamarket [7].

The papers did not show any clear definition of a data marketplace, therefore the search term "Data marketplace definition" was also included. It showed that there are several papers with informal definitions, but there are no clear definition that is widely used in academic papers.

Further the search term "Enterprise architecture AND data marketplace" was used to explore the EA modeling domain for data trading. The results did not include any papers on EA specifically for data marketplaces, which indicated a research gap that this master's thesis will help fill.

2.1.2 Inclusion and Exclusion Criteria

The project used a set of inclusion and exclusion criteria to help narrow down the literature review and select the most relevant papers. Table 2.2 shows the chosen inclusion and exclusion criteria for the project. The criteria to only include papers published between 1995 to 2021 was chosen since the data marketplace concept has most papers from this period and since it includes papers that show the current challenges and trends of data marketplaces. This criteria also help review relevant papers to identify an existing research gap.

The supervisors also recommended some relevant papers, technical reports and websites related to data marketplaces and EA modeling that were included in the literature review.

Table 2.2: Inclusion Criteria and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Studies published in English Language	Studies not published in English Language
Journal articles, conference proceedings, book chapters, web links, technical reports, patents	Not journal articles, conference proceedings, book chapters, web links, technical reports, patents
Published between 1995-2021	Not published between 1995-2021
Studies that provide answers to research questions based on title and abstract	Remove similar studies by keeping the most current and complete version
Studies related to Data Marketplaces or EA modeling	Studies not related to Data Marketplaces or EA modeling

2.2 Overview of the Data Marketplace Study Area

The section includes the literature review findings related to definitions or descriptions of a data marketplace, overview of a few of the current data marketplaces, overview of the data marketplaces for smart cities, overview of open data portals and overview of patent papers related to data marketplaces.

2.2.1 Data Marketplaces

As mentioned earlier, the findings show that there are no clear definitions of a data marketplace that is widely used in literature. This finding is also stated in the paper by Spiekermann et al. [2]. Due to this, a new definition of a data marketplace are proposed as a contribution of this master's thesis, and can be found in the Final Evaluations and Results chapter 8. Table 2.3 shows an overview of different definitions and informal descriptions of a data marketplace from the literature review papers.

Table 2.3: Definitions and Descriptions of a Data Marketplace

Definition	Authors
"We define a data marketplace as a platform on which anybody (or at least a great number of potentially registered clients) can upload and maintain data sets."	[8] [9]
"A data marketplace can be understood as a digital platform on which data products are traded."	[2]
"Facilitated by cloud-computing, these data markets offer a convenient single, logically centralized point for buying and selling data."	[10]
"Conceptually, data marketplaces are multi-sided platforms, where a digital intermediary connects data providers,data purchasers, and other complementary technology providers."	[11]
"Just like any other online marketplace a data marketplace is a platform that enables convenient buying and selling of products- in this case "data""	[12]

The findings show that there exists many hundreds data marketplaces, but it is a problem that many data marketplaces come and go according to the paper by Spiekermann [13] [2]. The website called "the Directory of Data Marketplaces" has a good overview of some of the current data marketplaces[13]. This page recently changed the business model to a platform called Datarade.ai. It is a platform for finding and comparing data from more than 2000 data providers and receive advice from data experts.

The literature review shows that there exist many academic papers related to data marketplaces, but the majority are research reports of specific implementations of data marketplace prototypes such as i3 and Datapace [14] [15]. The majority of the implementation papers focus on the trend towards decentralized data marketplaces with smart contracts. These reports are very relevant for this research project since they show the trends and challenges in the data trading landscape, which help address RQ1.

Table 2.4 shows an overview of some current data marketplaces based on findings from literature review.

<div align="center">

Table 2.4: Overview of Data Marketplaces

Name	Reference
i3	[14]
Datapace	[15]
Wibson	[16]
IOTA Data Marketplace	[17]
IDMoB - IoT Data Marketplace on Blockchian	[18]
Prodatamarket	[7]

</div>

Norwegian Data Marketplaces

As mentioned earlier, the literature review showed only one paper related to Norwegian data marketplaces. This is the paper about the SINTEF research project called Prodatamarket by Roman et al. [7]. This data marketplace sells and shares specific data from the building domain. A search in the NTNU Open repository of master's thesis showed the master's thesis of Ulversøy et al. that looks at privacy of individuals in decentralized data marketplaces[19]. The few related Norwegian research papers indicates a research gap. This master's thesis will help fill this research gap by specifying requirements and designing a data marketplace prototype and EA model that use the Norwegian smart city Trondheim as example.

Data Marketplace Patent Papers

The findings from the literature review showed that there exists several patent papers related to data marketplaces, for instance the patent paper from Anand et al. for a data marketplace for municipal services [20]. Table 2.5 shows an overview of some of the patent papers related to data marketplaces. The "Open data marketplace for municipal services" patent is relevant for the project, since it addresses some of the same research questions as the project and describes alternatives for payment methods[20].

2.2.2 Smart City Data Marketplaces

There also exist several research papers related to data marketplaces for smart cities, for instance the i3 market, Datapace and Wibzon [14][15] [16]. The find-

Table 2.5: Data Marketplace Related Patent Papers

Name	Reference
Open data marketplace for municipal services	[20]
Apparatus and method for providing a data marketplace	[21]
Platform data marketplace	[22]
Leveraging data in data marketplace environment	[23]
Personal data marketplace for genetic, fitness, and medical information including health trust management	[24]

ings from these papers are very relevant for this research, since they help address RQ2 for what is needed in a smart city data marketplace. The papers contribute with the data marketplaces' details and communications technology architectures (ICT) that provide a better understanding of the data marketplaces. This helps inspire the choices in the EA model, customer journeys and prototype for the new smart city data marketplace. The papers are also relevant for addressing RQ3, regarding how EA modeling and customer journeys can support the planning and design of a smart city data marketplace.

The topic of data sharing in smart cities is also explored in the ATIS report which proposes a framework for smart city data sharing[25]. Additionally, the paper by Box et al. explores the landscape of data platforms in smart cities [26].

The master thesis by Välja et al. explores the need for a data marketplace in the smart city Stockholm, Sweden [27]. The thesis is relevant for this project since it addresses similar research questions as RQ2, by exploring the need for a data marketplace in a Nordic smart city. A limitation is that there was not developed any prototype of the data marketplace. The research project will develop an EA model and data marketplace prototype that can also be suitable for the needs of other smart cities such as Stockholm.

Table 2.6 shows an overview of papers on data marketplaces for smart cities. Many of the data marketplaces have titles that ends with "for smart cities". This is a clear indication that they involve data marketplaces for smart cities. Nevertheless, the papers does not focus much on the fact that the data marketplaces are specialized on smart cities, and "smart cities" are only mentioned one or two times. All the data marketplaces in table 2.6 use decentralized technologies which indicates that there is also a trend for blockchain in the specific smart city data marketplace context.

The literature review did not show any definitions of a smart city data marketplace, and the master's thesis will propose such a definition in the Final Evaluations and Results chapter 8.

2.2.3   Open Data Portals

Most of the papers in the literature review only consider data for sale and does not cover the sharing of open data in the data marketplaces. The master's thesis

Table 2.6: Smart City Data Marketplaces

Name	Reference
Towards Smart City Marketplace at the Example of Stockholm	[27]
Towards a Decentralized Data Marketplace for Smart Cities	[28]
A decentralized marketplace for M2M economy for Smart Cities	[29] [30]

will help extend the research on data marketplaces with both open data and data for sale. On the other hand, there are many papers about open data portals which are emerging in many cities and countries. These are portals for sharing of free open data from the city and government with the citizens. Some examples are the open data portals for London and Paris and the common open data portal for European open data called the European open data portal[31]. Table 2.7 shows an overview of some of the open data portals in Europe.

Table 2.7: European Open Data Portals

Name	Country or city	Reference
Trondheim kommune datasets	Trondheim, Norway	[32]
Open data Trondheim	Trondheim, Norway	[33]
data.norge	Norway	[34]
European data portal	Europe	[31]
Danmark open data	Danmark	[35]
London data	London, UK	[36]
UK data portal	UK	[37]
Paris open data	Paris, France	[38]
Data gouv	France	[39]
Dati gouv	Italy	[40]
Data Piemonte	Piemonte, Italy	[41]

The paper by Barns explores the trend of open data portals in urban governance[42]. Many open data portals use the open source CKAN data managing system, such as the open data portals of Singapore, Australia and Canada [43].

The background study of open data portals showed that there also exist two open data portals for Trondheim [32][33]. The portals seem to be in the early stages of launching, since they have very few datasets available. Nevertheless, the two portals are interesting to review to get inspiration on how to design a smart city data marketplace for Trondheim.

The study of the open data portals are very relevant for understanding the important aspects of open data sharing. The papers and websites are also useful

for addressing RQ2 about what is needed in a smart city data marketplace. The open data portals are quite similar to data marketplaces, since they both share data and aims to make data more accessible. The major difference is that the open data portals only have free open data available and data marketplaces mainly have data for sale and functionality for selling and buying data. The designs of the two platforms types often look similar, with search bars for searching for datasets, data categories and similar types of data file types to download. The open data portals are designed to be ease to use for the citizens. Therefore open data portals are important inspiration for designing data marketplaces for smart cities. The open data portals are extra relevant for the master's thesis, since they are focused on one location, a country or a city rather than a general global platform.

There also exists a platform with free data for machine learning competitions called kaggle.com, which has a nice design and user experience [44].

2.3   Overview of Prior Related Studies

This section includes an overview of the prior related studies for data marketplaces that were included in the literature review.

The literature review identified papers, journals, conference proceedings, technical reports, Master Thesis Reports and patent papers. The papers were chosen since they help answer the research questions and understand the data trading landscape. The list of prior studies can be found in table 2.8.

Table 2.8: Prior Studies on Data Marketplaces

Title	Country	Reference
Towards Smart City Marketplace at the Example of Stockholm	Sweden	[27]
Marketplaces for data: An initial survey	Germany, New Zealand	[8]
The data marketplace survey revisited	Germany	[9]
Data Marketplaces: An Emerging Species	Germany	[45]
The (Unfulfilled) Potential of Data Marketplaces	Finland	[3]
The significant role of metadata for data marketplaces	Germany	[12]
A metadata model for hybrid data products on a multilateral data marketplace	Finland	[46]
Pricing approaches for data markets	Germany	[47]
Data Marketplaces: Trends and Monetisation of Data Goods	Germany	[2]
Dont Buy A Pig In A Poke A Framework for Checking Consumer Requirements In A Data Marketplace	Germany	[48]
Open data marketplace for municipal services	US	[20]
Data Marketplace as a Platform for Sharing Scientific Data	India	[49]
Decentralized data marketplace based on blockchain	UK	[15]
proDataMarket: a data marketplace for monetizing linked data	Norway	[7]
Wibson: A decentralized marketplace empowering individuals to safely monetize their personal data	Switzerland, Austria, US	[16]
(i3) Towards a decentralized data marketplace for smart cities	US	[28]
A decentralized marketplace for M2M economy for Smart Cities	Italy	[30]
Smart cities and urban data platforms: Designing interfaces for smart governance	Australia	[42]
Data Platforms for Smart Cities: A Landscape Scan and Recommendations for Smart City Practice	Australia	[26]
A survey on big data market: Pricing, trading and protection	US, China	[50]
Data markets in the cloud: An opportunity for the database community	US	[10]
Data Sharing Framework for Smart Cities	US	[25]

2.4   Review of Current Practices

This section includes a review of current practices for data marketplaces and EA modeling. The subsections covers the types and characteristics of data market-

places, challenges, benefits and trends of data marketplaces, centralized and decentralized network types, smart contracts, tokens and crypto currencies, security and trust, data types, metadata, life cycle of data, pricing models and EA modeling for data marketplaces.

2.4.1 Types and Characteristics of Data Marketplaces

The survey papers by Stahl et al. identifies two types of data marketplaces, the multilateral and the domain specific data marketplaces [8] [9]. A multilateral data marketplace sells different types of data. The domain spesific data marketplace are specialized towards one type of data or field, such as personal data, IOT sensor data or building data like the Prodatamarket. The marketplaces can have business models that sell data from business to business(B2B), customer to business (C2B) and business to customer (B2C).

There are three main roles in a data marketplace, the data consumer (buyer), the data provider (seller) and the data marketplace owner or administrator. Additionally the role prosumer involves customers that use the data marketplace for both selling and buying data.

The survey papers by Stahl et al. consider the following aspects as important for data marketplaces; Type (raw, enriched etc), Time frame, Domain, Data Origin, Pricing Model, Data Access (API, download etc), Pre-purchase testability, Pre-purchase information, Data type, Target audience, Trustworthiness, Size of vendor and Maturity.

Data Types

According to the survey papers by Stahl et al. there are two types of data on most data marketplaces, static dataset files that can be downloaded or dynamic real-time data streams that can be accessed via application programming interfaces (APIs) [8] [9]. The static historical datasets are preferred when the buyer needs the whole dataset and are not interested in the real-time data. Dynamic real-time data is needed when the buyer wants the data from right now and are not interested in the whole historic dataset [12].

Common file types in the data marketplaces are CSV, XML, JSON, TSV, PDF.

Life Cycle of Data

The life cycle of data is relevant for this project, but it was not covered in most of the papers related to data marketplaces, besides the paper by Lawrenz et al. [12]. The term is relevant since the selling, buying and sharing of data is an important part of the life cycle of data. Topics such as intervals for updates and continuous updates were introduced in the expert evaluation feedback and are related to life cycle of data. This indicates a need for more research on life cycle of data related to data marketplaces.

2.4.2 Challenges of Data Marketplaces

The paper called the unfulfilled potential of data marketplaces by Koutroumpis et al. and the survey papers about data marketplaces by Stahl et al.list several chal-

lenges of data marketplaces [3] [9]. The main challenges for data marketplaces are related to the following aspects:

- The arrow issue, concerning how to know the value of a dataset [3]
- The need for high quality data, and the quality aspect is a subjective aspect that is difficult to generalize [3] [9] [12]
- Trust in the sellers and the buyers [3]
- The difficult legal issue of data ownership [3]
- Security of the transactions [3]
- Privacy legal issues, (GDPR) the general data protection regulations of EU [3]
- Difficulty to stay in the data trading market, many data marketplaces come and go. [3] [9]

According to the paper by Spiekermann, several data marketplaces have come and disappeared after some years such as Azure Data Marketplace, InfoChimps and Kasabi [2]. This indicates that it is challenging to stay in the data trading market.

The paper by Koutroumpis et al. shows the unfulfilled potential of data marketplaces and is relevant for this research project since it highlights aspects of data marketplaces that need more research and has potential for improvements [3]. For instance the need for clearer data ownership are mentioned and the issue of platforms disappearing or not being able to last for a long time. The paper addresses similar research questions as RQ1, regarding what is a data marketplace and what are the main trends and challenges in the domain.

The paper by Balazinska et al. discusses opportunities for the database community to contribute to fix challenges related to data marketplaces, specially the challenges of pricing models [10]. They discuss issues related to how the pricing models such as subscription with n number of API queries does not consider the quality of the data for the pricing. They also suggest to have a advisor for selecting the correct price for the sellers when uploading new datasets, as well as services for data anonymization before uploading and cleaning data after purchase etc.

The need for regular updates of the datasets and a good way to find the most suitable and high quality data is mentioned as a big challenge in the paper by Spiekermann [2]. It also looks at the challenge of selecting the right data marketplace to fit the customer requirements.

An aspect that is reviewed to be very important for data marketplaces based on literature review findings is the need for high quality data and different possibilities to check the quality of the data before buying, especially by having structured and relevant metadata [12].

2.4.3 Benefits of Data Marketplaces

For data buyers the data marketplace make it easy to find new and relevant datasets, and for the data sellers it makes it easy to make money from their data.

The paper by Ghosh explores the idea of a data marketplace for scientific data, and shows some of the potential benefits of this platform [49]. This paper is relevant since one of the user groups of the smart city data marketplace is researchers in the smart city. The benefits are also relevant to a smart city data marketplace.

The main benefits of data marketplaces are as follows:

- Make data more accessible
- Help discover and compare datasets, ratings and comments of datasets
- Provide a business model for data trading and rewards the sellers
- Provide good storage
- Neutral third party platforms can motivate data enhancement
- Can also offer technical services on top, such as data organization, cleaning
- Protects data ownership

2.4.4 Trends of Data Marketplaces

The literature review findings show that there are several papers that explore the trends in the data trading landscape, for instance the two survey papers by Stahl et al. [8] [9]. The papers show an overview and comparison of selected data marketplaces and their differences in aspects like access types, business models, payment models, pre-purchase testability, data types etc. These papers are very relevant for the master's thesis since they help address RQ1 by highlighting the trends in the domain. The papers make it easier to understand the needs and functionality and design choices for general data marketplaces.

The two survey papers are from 2012 and 2014 and due to the long time since the publication there are new trends and aspects of current data marketplaces that are not covered. This identified the need for new and up to date research and surveys on the data trading market for 2021.

The first survey from 2012 showed that need for high quality data and the willingness to pay for this kind of data[8].

For instance one of the aspects that is important in a data marketplace is the need for pre-purchase testability, which means that you are able to download and test a section of the dataset before you decide whether or not to buy it [8] [9].

Another finding from the literature review is the trend of transitioning from centralized towards decentralized data marketplaces such as the data marketplaces i3, Datapace and Wibson [14][15] [16]. The paper by Spiekermann discusses the trends of data marketplace and monetization of data goods [2].

Findings from the literature review shows that the main trends in the current data marketplace landscape are as follows:

- Decentralized network type
- Smart contracts
- Pricing models
- Crypto currencies
- Tokens

2.4.5 Centralized and Decentralized Network Types

Another identified trend from the literature review findings is the trend of going from centralized towards decentralized data marketplaces. Centralized means that there is a central authority that controls the data marketplace, and decentralized marketplaces on the other hand means that the marketplace has no middle man. There are many arguments for going towards a decentralized data marketplace and the literature review findings a number of marketplaces that lean towards the decentralized network type, for instance the i3 market, Datapace and Wibson [14] [15] [16]. Both centralized and decentralized data marketplaces were studied in the literature review.

These decentralized applications (DApps) have the advantage that they are immutable. This means that once it is created it can not be changed by a single user and there is no single point of failure [51]. Disadvantages with decentralized network type are that it is built on the blockchain technology which uses huge amounts of energy[51]. A centralized data marketplace is a system where there is a middleman that owns and manages the system.

Figure 2.1 and 2.2 illustrate the decentralized and centralized network types.
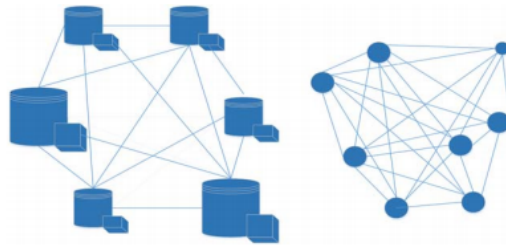
Figure 2.1: Illustration of the Decentralized Network Type, Illustration from [25]
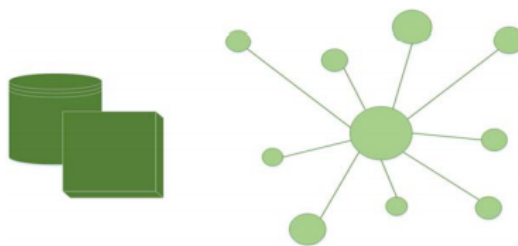
Figure 2.2: Illustration of the Centralized Network Type, Illustration from [25]

There is also a possibility to use a hybrid, partly decentralized network type [2]. This provides some of the benefits of the decentralized network type, and the platform can still have centralized storage which makes it easier to access datasets for non-technical users of the data marketplace.

2.4.6   Tokens and Crypto Currencies

There is also a possibility to use crypto currencies like Ether or Bitcoin to pay for data in some data marketplaces. Other data marketplaces use internal tokens that can be used trade the datasets, such as the Datapace data marketplace[15]. The IOTA data marketplace use the IOTA to pay for the data [17].

2.4.7   Smart Contracts

One of the aspects that can make a platform decentralized or partly decentralized is smart contracts. The smart contract was introduced by Nick Szabo in 1997 [52]. A smart contract is an electronic contract and piece of code that automatically executes when the terms of the contract have been fulfilled. This technology is used by both Datapace, i3 and Wibzon [14][15] [16]. This means that there is no need for third parties like a bank or a lawyer and it is built on the blockchain technology which makes it immutable and difficult to tamper with after it is signed. The smart contract is reviewed to be an interesting aspect to include in the proposed prototype in chapter 4. The i3 research project has developed an open source Smart contract which is programmed in the language Solidity and can be used in other data marketplaces [14].

2.4.8   Pricing Models

There exist many pricing models for data marketplaces and according to Spiekermann the most common models are the pay-per-use, pay pr. month (subscription) and pay pr. package of data [2]. The survey paper on big data markets by Liang et al. and the paper by Muschalle et al. also discusses the pricing models of data trading [50] [47]. According to the survey by Stahl et al. the most popular option is the Pay pr. package of data model [9] [8] [2]. The Freemium model means that you get the normal functionalities for free and must pay for more functionalities, but it is not so popular in the current data marketplaces[9] [8].

   The sellers and buyers might also have to pay an administrative fee or membership fee. In decentralized data marketplaces such as Datapace or Wibson, there is the possibility to pay a "notary" which is an individual in the network that can check that the data is valid and correct [16] [15].

2.4.9   Metadata

Metadata can be defined as data about data [12]. The metadata can for instance describe where the data comes from, what the data is about and when it was created. According to the paper by Lawrenz et al. metadata is the most important aspect for selling data. It is very important for data quality on a data marketplace and specially to aid the buyers in evaluating whether to buy the data or not[12].

   Data is different to other types of products that are sold in online marketplace, since it is more difficult to describe the product for the buyers. It is difficult to know

the quality of the data and it is not possible to return the data when it is bought, since it can be copied by the buyer. Data quality is difficult to rate since quality is objective and depends on personal requirements. Nevertheless, metadata can help resolve this challenge since it can be used to check if the data meets the buyer's requirements by providing data about the data product.

There are several standards for metadata, one of which is the Dublin Core Metadata Standard. It includes 15 semantic definitions for the data such as title, creator, subject, publisher, type and language etc [53].

Real-time and static data needs different types of metadata according to Lawrenz et al. [12]. This is since the data types are quite different in nature and it is important to consider for the metadata in the data marketplace. For real-time data it is for instance important to show where the data comes from, what it is about, what file format it has, number of data points it has, but not what period it is from, since it is continuous real-time data.

Some metadata can be automatically retrieved from the data such as the file size, timestamp and file type, and some information needs to be filled out manually by the seller such as the data description.

2.4.10   EA Modeling for Data Marketplaces

The literature review findings show that there is no research on EA modeling of data marketplaces, but there are many papers on EA modeling of smart city systems in general such as the papers by Petersen et al. and Pourzolfaghar et al.[54] [55]. This is an identified research gap and this master's thesis will help to fill this research gap by providing a developed EA model for the new smart city data marketplace.

The EA framework TOGAF stands for the open group architecture framework and is widely used in the EA industry [56]. EA modeling and specifically versions of TOGAF has been used in many research papers for modeling systems in smart cities[54]. The +CityxChange project has developed an EA framework which is an expansion of TOGAF. The EA framework have extra layers focus on the data layer and is used to model systems in European smart cities[4]. The +CityxChange project shows that EA modeling has proven to be a good approach for modeling systems in smart cities.

The Industrial Data Space Reference Architecture Model (IDS-RAM) technical report discusses data marketplaces and the use of their reference architecture model [57]. Figure 2.3 shows the IDS-RAM. Other EA frameworks such as Zachman framework, TOGAF and 4EM could also support data marketplaces, but they do not focus much on the data layer which is important for a data marketplace[58] [56].
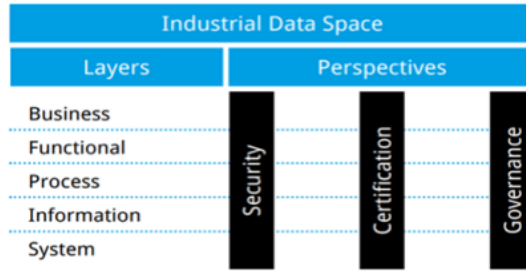
Figure 2.3: The structure of IDS-RAM. Figure from [57]

The +CityxChange EA framework

The +CityxChange framework is good for modeling a data marketplace since it focuses on the data aspects in the data layers of the framework. It consist of 7 horizontal layers and 4 vertical perspectives. Figure 2.4 shows the different layers and perspectives of the framework. The horizontal layers are the context layer, the services layer, the business layer, the application and data processing layer, the data space layer, the technologies layer and the data source layer. The vertical perspectives are the security perspective, the stakeholders, the Policies and Regulations, the Privacy and Trust, the Ownership and Access, the Interoperability, the Data Security and Risk Assessment and Data Governance Perspectives [59][54][60]. Figure 2.5 shows the main steps of using the +CityxChange framework.
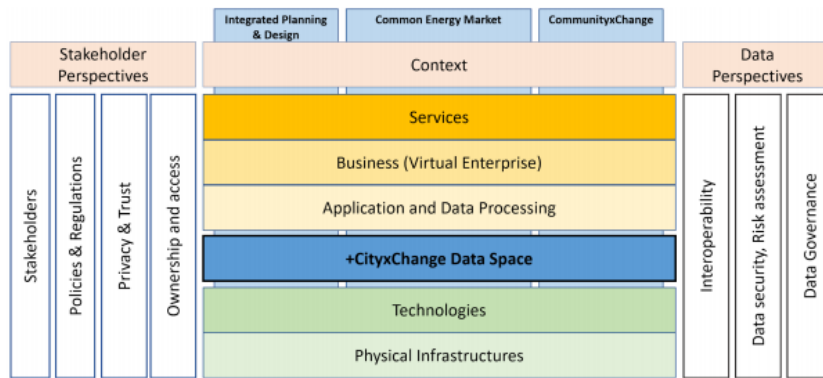
Figure 2.4: The layers and perspectives of the +CityxChange EA framework. Figure from [59]

Figure 2.5: The main steps of using the +CityxChange EA framework. Figure from [59]

The EA modeling methodology is a method that helps to understand the whole system and see it from different perspectives. It is a standardized method to model a system, and makes complex systems easier to understand by making high level models.

2.5 Background Study of Existing Platforms

This section includes a study and review of a selection of existing data marketplaces, open data portals and electronic marketplaces. It also shows positive features of the platforms that inspired the planning and design of the smart city data marketplace. Table 2.9 shows the selected data marketplaces for the study of existing platforms.

Many of the existing data marketplaces in the data trading landscape did not appear in the literature review papers. Therefore it was also important to search for the websites directly in addition to the papers to see the existing trends and designs. The study of existing platforms was beneficial since the designs and layouts are often not covered in the papers. The user experiences are also easier to evaluate through testing the actual platforms.

Table 2.9: Background Study of Existing Platforms

Name	Type	Features	Reference
i3 Intelligent IoT integrator	Data marketplace	Smart contract, IoT focus	[27]
Datapace	Data marketplace	Smart contract, tokens, easy to use design	[15]
Wibson	Data marketplace	Smart contract	[16]
IOTA Data Marketplace	Data marketplace	Tokens IOTA	[17]
ProDatamarket	Data marketplace	Building data	[7]
Trondheim Kommune Data	Open data portal	Simple design	[33]
Trondheim Open data	Open data portal	Category buttons	[32]
Data.Norge	Open data portal	Links to available open data in Norway	[48]
European Data Portal	Open data portal	Category buttons, Links to open data portals in EU	[20]

Data Marketplaces

The review of existing data marketplaces showed the trend towards more decentralized platforms such as i3, Datapace and Wibson. Their papers provided examples of how smart contracts can look like. There are not many good design examples of smart contracts for marketplaces in general, but the prototypes of i3 and Datapace showed a preview of how smart contracts can look like.

The Datapace paper states that the goal is to have a design that is similar to existing websites and familiar for the users [15]. This is also one of the goals for the proposed smart city data marketplace prototype in chapter 4-7. Datapace have a very understandable and intuitive design and therefore it was used as a starting point for the design process.

Open Data Portals

The background study of existing open data portals showed many active platforms with intuitive and simple design and user experience. Many of the portals have tiles with categories to navigate to a specific category of data. These portals only show open free data that can be downloaded or accessed through an API. The open data portals are good inspiration for how to display and search for open data. Naturally, the open data portals do not include payment methods and pricing models, which the data marketplaces also needs.

Electronic Marketplaces

The background study of electronic marketplaces such as Finn.no and Ebay also provided inspiration on common design features for online shopping experiences, such as the cart, check out, several payment methods, help page, FAQ, search, filtering, ratings and display of products.

Common Components and Functionalities

The identified common functionalities and pages for data marketplaces are as follows:

- Registration and login
- Search for datasets
- Filter the search
- Select a dataset
- Information page for dataset
- Check out and pay for the dataset
- Register and upload a new dataset
- Rate a dataset

Design and User Experience The background study of the data marketplaces in table 2.9 shows that the design of the data marketplaces are similar in many aspects. Some of the data marketplaces are research projects with less focus on the design and user experience and more focus on the technical implementation in the initial versions of their prototypes. This is the case for the i3 data marketplace [14].

A limitation for the user experience of some of the data marketplaces is to display large amounts of different information on the pages which can lead to overload, confusion and bad user experience. Several open data portals have interfaces were the users need to have high experience with data analysis and technical language to be able to find and access the data. Additionally, it seems to be more difficult to use decentralized data marketplaces compared to centralized platforms, since the decentralized data marketplaces are often more complex. It would be an advantage to improve the accessibility and user experience of these

platforms, to increase data sharing and usage.

2.6   Synthesis of the Literature Review

This section includes the synthesis of the literature review with the identified high level needs, requirements and focus aspects for the new smart city data marketplace.

The identified high level needs and requirements for a smart city data marketplace are as follows:

- There is a need for a specialised data marketplace for smart cities like Trondheim
- There is a need to help fill the research gap for EA modeling of Data marketplaces
- There is a need for a clear definition of a data marketplace and smart city data marketplace
- The smart city data marketplace should have functionalities for easy buying and selling of data and finding and sharing of free open data.
- The design of the smart city data marketplace should focus on smart city aspects, accessibility and customer needs, good user experience, scalability and quality of data.

The focus aspects that are identified as important for the new smart city data marketplace were smart city aspects, ensuring accessibility with focus on customer needs, good user experience, ensuring trust and security, scalability of the data marketplace and high quality data.

Smart City Aspects

The choices of domains in the prototype were influenced by the widely used domains for smart cities. Datasets in the health domain could for instance be covid-19 patients statistics from St.Olavs Hospital in Trondheim. Data from the energy domain could be energy consumption statistics from TrønderEnergi and data from the mobility domain could be datasets from the bus company AtB in Trondheim.

Accessibility and Customer Needs

The new smart city data marketplace should be easy to use to find/buy/upload datasets. Pages such as "help", "how to get started", "tips and tricks" and "forum" pages and "welcome" and "about" sections can help new customers get started on the platform. The goal is to make a design that is simple and understandable for all the potential users of the data marketplace. Users that are familiar with electronic marketplaces should be able to understand and use the data marketplace without much misunderstandings. The main design elements for searching and buying a product aims to be recognizable from other electronic marketplaces.

User Experience

Nielsons 10 heuristics of good user interface design is important to consider when planning and designing the prototype[61]. Don Norman's Design Principles

are also very important to have in mind and it includes the aspects visibility, feedback, constraints, mapping, consistency and affordance [62].

Trust and Security

Trust in the seller and buyer is important in a data marketplace, and the design of smart contracts are one way that aims to improve trust in the system. The trust can be improved with the help of smart contracts, since the it ensures that the buyer will automatically receive the dataset, when both the buyer and seller has signed the smart contract and the seller has received the payment.

Scalability

The prototype should focus on scalability of the data marketplace, since the number of datasets, users, domains, pricing models or available data types could grow.

Quality of Data

The quality of data and the possibilities to evaluate the quality or relevance of the data is important in the data marketplace. Aspects that may help with this challenge are ratings and reviews of the data, pre-purchase testability and relevant well structured info about the dataset.

2.7 Updated Research Questions

The research questions were reviewed and updated with new sub research questions based on the findings from the literature review.

The new sub research questions are defined as follows:

- **RQ1:** What is a data marketplace and what are the main challenges and trends in the data marketplace landscape?

  RQ1.1: How can we best define the concept of a data marketplace?
  RQ1.2: What are the main trends in the data trading landscape?
  RQ1.3: What are the major challenges related to data marketplaces?
  RQ1.4: What are the limitations of the existing smart city data marketplaces?

- **RQ2:** Is there a need for a data marketplace for a smart city like Trondheim and what is needed in such a platform?

  RQ2.1: How to design a data marketplace that supports the needs of a smart city and what is the important functional and non-functional requirements for such a platform?
  RQ2.2: How can we best ensure quality of the data and trust in the data marketplace?
  RQ2.3: How to make both open data and private data available in the data marketplace?
  RQ2.4: Do we need one data marketplace for each city or a common plat-

form for several smart cities?

RQ2.5 Should we use a decentralized or a centralized network type for the smart city data marketplace?

- **RQ3:** How can EA Modeling and Customer Journeys support the planning and design of a data marketplace?

    RQ3.1 What is the existing work on EA modeling for data marketplaces?

    RQ3.2: What is the benefit or added value of using EA modeling and customer journeys in the design of data marketplaces?

    RQ3.3: How can EA modeling be used to show stakeholders with multiple roles in different scenarios?

    RQ3.4: How to model all the elements of a data marketplace such as the decentralized network type, data sources, data types, technology stack, business organisations etc with EA?

2.8 Summary

The chapter has shown the literature review methodology, the overview of the study area, the review of current practices, the related prior studies, the background study of existing platforms, the synthesis of the literature review and the updated research questions.

Chapter 3

Methodology

This chapter includes the research design, the research approach, the research methodology and the data analysis methods.

3.1 Research Design

The masters' thesis used an agile approach with four system design iterations. The research flow consisted of literature review, service design with personas and customer journeys, EA Modeling, prototyping, user testing and expert evaluations of the proposed data marketplace. Figure 3.1 shows the research flow of the project. It was necessary to conduct literature review in parallel to other research methods. The findings from the literature review supported the requirement specifications and the development of the customer journeys, personas, EA model and the design prototyping.
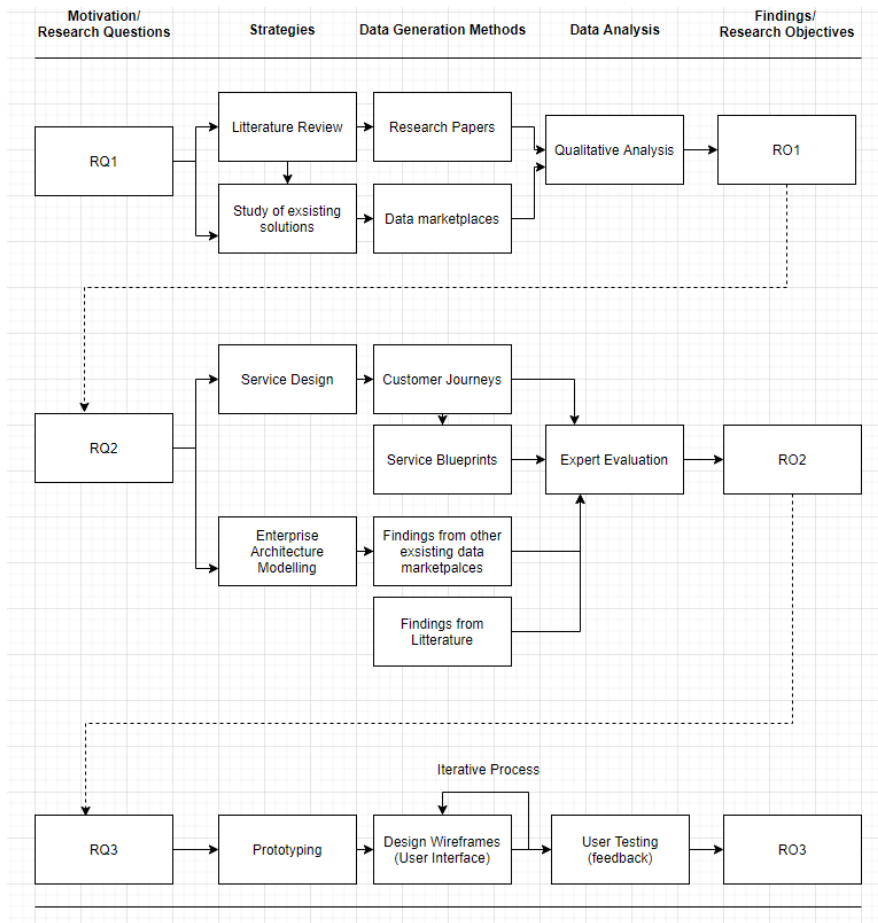
Figure 3.1: The figure shows the research flow of the project.

3.1.1 Implications of the Covid-19 Pandemic

Due to the Covid-19 restrictions during the thesis work, the biweekly supervisor meetings, user testing and expert evaluation sessions were held digitally instead of in-person. They were conducted via the digital communication tool Microsoft Teams. The digital meetings may have made it more difficult to observe body language and facial expressions. Nevertheless, Microsoft Teams made the meetings streamlined and it was easy to make audio and video recordings through the built-in functionality. The tool was chosen since NTNU has a data agreement with Microsoft and since it has both screen sharing and recording functionality, which is useful during user testing and expert evaluations.

3.2 Research Approaches

The chosen research approaches for the master's thesis was Service design including personas and customer journeys, the EA modeling, design prototyping and

user testing. There were four system design iterations that all consisted of personas, requirements specifications, Customer Journeys, EA modeling, prototyping and user testing or expert evaluations. There were also conducted evaluations of the EA modeling and customer journeys approaches for planning and designing a data marketplace.

The full stack development of a working complex data marketplace was considered, but it was not an objective of this thesis due to the scope and time restrictions of the master's thesis. The scope of the project focused on requirement specifications, planning and design of the smart city data marketplace with help of EA modeling and service design approaches. There were no customer or predefined requirements for the project which required extra efforts to investigate and understand the related topics of data trading and specify relevant requirements.

3.2.1 EA Modeling

What: The EA modeling approach involves modeling of all the different relevant aspects of an enterprise as a socio-technical system, including business processes, organisation, technologies etc and helps to show the system from different perspectives [63].

How: As mentioned in the Literature review chapter 2, there exist several different EA frameworks that could be used for the EA modeling in this project. The +CityxChange EA framework was tested out by modeling some existing data marketplaces. The testing showed that the framework was able to capture the important aspects of the data marketplace. The framework was also suitable since it has an extra focus on the data layer which is important for a data marketplace. Furthermore, the EA model of the new smart city data marketplace was developed based on findings from the literature review. The proposed EA model was updated in each of the four system design iterations when the requirements of the system changed. The EA models can be found in chapter 4-7. The tool Archi was chosen for the EA modeling since it is free, specifically developed for easy EA modeling and is widely used in the EA industry [64].

Why: The approach was chosen since the researcher had prior experience with EA modeling from the NTNU course TDT4252 and wanted to use the experiences in the master's thesis [65]. The EA modeling approach was also chosen since it is suitable for developing high level models of complex systems like data marketplaces. It is a thinking tool that helps to consider and understand the components and processes in the whole system and remember the different perspectives of stakeholders. The initial tests of modeling existing data marketplaces with the +CityxChange EA framework provided a better understanding of how to use the framework. It also helped understand the data marketplaces and choose what aspects to include in the EA model and prototype of the new smart city data marketplace. In the start of the project a lot of time was spent on understanding the concepts, the framework and how to use it to model the data marketplace.

3.2.2 Service Design

What: The Service design approaches involve designing a service or services by developing customer journeys, personas and blueprints [66].

How: The master's thesis used the two approaches customer journeys and personas. Service blueprints were also tested out, but were not used further since it did not provide much for the project. The services layer in the EA model helped show similar aspects as the service blueprints. The Customer journeys approach involves creating diagrams with boxes and arrows that show all the steps that a customer needs to take to do a specific task on the platform. An example of a customer journey for the smart city data marketplace could show all the steps that were needed to upload a new dataset. The Personas approach consists of developing fictive representations of potential customers of the data marketplace.

Why: The service design approaches were also introduced in the NTNU course TDT4252 and inspired the choice of combining both EA modeling and service design approaches. The customer journeys approach was chosen since it helps to understand and visualize all the small steps that a customer needs to go through when using the smart city data marketplace. It also makes it easier to identify what steps needs to be shortened or changed. Another benefit is that customer journeys forces the researcher to think from the customer's perspective. The customer journeys are helpful to plan which pages and functionalities are needed in the system and how to make a good user experience. The Personas was used since they help to see the perspective of the different potential customers. It helps design the customer journeys and data marketplace prototype that fits the needs of the personas. The use of Personas and Customer journeys helped answer RQ2 by showing the potential customers and which steps were needed or not for the user experience in the smart city data marketplace. The Personas and Customer journeys were changed and updated based on findings from literature review and feedback from user testing in each of the four iterations. They can be found in the next four chapters 4-7.

3.2.3 Prototyping

What: The prototyping approach involves designing the system.

How: The prototyping was done in Figma which is a tool for designing interactive prototypes [67]. The different pages of the platform was designed based on the customer journeys that show all the steps a customer needs to take to do a task on the platform. In the first system iteration the most important functionalities were designed, such as pages for search for data and upload data.

User testing sessions were used as an important part of the prototyping process to rapidly identify logic errors, flaws in the user experience, bad choices of names or symbols and get feedback from users about what they like and don't like, and what could be improved. After the user testing the suggested improvements were implemented. The prototyping was a very iterative process with a lot of feedback and changes. The expert evaluations also provided many interesting improvement

suggestions for the prototype. The four versions of the proposed smart city data marketplace prototype can be found in the next four design iteration chapters 4-7.

Why: The prototyping approach was chosen since it was a suitable approach for addressing RQ2 and designing a prototype of the smart city data marketplace, to get a more concrete idea of how the design and user experience of such a platform could look like.

3.2.4 User Testing

What: The user testing approach involves testing the prototype on users, observe how the tester uses the system and get feedback on what they liked and suggestions for what aspects that need to be improved.

How: There were conducted user testing in each design iteration with one participant in each user testing session. In the user testing sessions the participants were told that the purpose was to test the prototype and not to test them. The participants were encouraged to think aloud during the session. In the session the participants got a set of predefined user stories that they should test out in the prototype. An example of a user story is "As a user I want to find the TW Temperature dataset and buy the dataset - how would you do that?". The participants of the user testing were six Trondheim citizens and three participants from other cities that could be potential customers of the data marketplace. The same structure of user testing was used in the start of the expert evaluations. The first iteration of the prototype was tested by one participant for approximately 3 hours to get initial feedback on the idea and the design. The second iteration prototype was tested by two participants for approximately 1 hour each. In the third iteration the prototype was tested by five experts in 40 minutes each and the fourth iteration prototype was tested on three experts in 40 minutes each.

Why: The approach was chosen since it tested and provided feedback on the prototype throughout all the iterations of the prototyping process. It helped provide feedback on what aspects were good and not so good, and how it could be improved. The user testing was done digitally, by sharing the screen and letting the participants click and use the prototype from their own computer. This was useful since it provided a way to see where the participant clicked when trying to do different tasks, as well as hearing their explanations of why and how they were thinking. Since the user testing was conducted with Microsoft Teams it was very easy to make both audio and video recordings of the session within the tool. A limitation from the digital user testing might be that facial expressions and body language may have been more difficult to observe, compared to physical face to face user testing.

3.2.5 Double Diamond of Design

What:

The choice of research approaches and methods were inspired by the phases in the Double diamond process. The Double diamond is divided into the four

phases discover phase, the define phase, the develop phase and the deliver phase [62]. Figure 3.2 shows the different phases of Double Diamond. These phases were taken into account when choosing the approaches and methods used in the research design.

How: The first phase consisted of literature review and background study of existing platforms.

The next phase consisted of EA modeling of a few existing data marketplaces to get a better understanding of the concept. Next the EA modeling was used to model and plan the new data marketplace. The customer journeys were also developed in this phase and both the EA model and the customer journeys evolved based on findings from the study of literature and existing platforms.

The third phase consisted of development of the prototype design with four iterations and user testing to get feedback from potential users.

The phase also had expert evaluation sessions of the prototype and evaluations of the EA modeling and customer journeys approaches.

The fourth and last phase consisted of finalizing the project.

Why: The Double diamond process was used for inspiration since it is widely used in design of web applications and it is a good inspiration for what aspects and phases need to be considered and included for the design process of the data marketplace. The double diamond was also introduced in the Enterprise architecture course TDT4252.
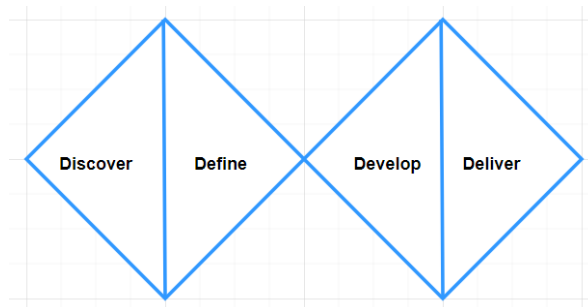
Figure 3.2: The Double Diamond process.

3.3 Research Methodology

The research methodologies that were used in this project were literature review including background study of existing platforms and the expert evaluation interviews methodology. The explanation of the literature review method can be found in the Literature review chapter 2.

Other seemingly relevant research methodologies as for instance questionnaires were also considered for the evaluations of the prototype, but were not selected since the questionnaire method was considered to give less thorough details compared to semi-structured expert interviews. In the interviews there are room to have follow-up questions and more interactive and in-dept sessions were

you also can observe where the participants clicks on the screen and hear what they are explaining when thinking out loud.

3.3.1 Expert Evaluations Interviews

What: The expert evaluation interview method involves evaluating the proposed prototype and concept of the smart city data marketplace by experts in the domain[5].

How: The expert evaluation session consisted of a semi-structured interview with four phases; (1) gathering info about the participants, (2) user testing of the proposed prototype, (3) feedback from the user testing and (4) TAM inspired questions.

The first phase included gathering demographics and prior knowledge level of related topics (self evaluations) for the participants. The participants were also asked to describe the concepts of a data marketplace and smart city data marketplaces in their own words.

The second phase included user testing with a set of user stories that the participant tested out. An example for a user story are "As a user you should find data related to weather and select the TW Temperature dataset - how would you do that?". The experts were encouraged to think aloud when testing the prototype and they were told that the purpose of the testing was to test the prototype and not the participant.

The third phase included the feedback from the user testing and suggestions for improvements of the prototype, in addition to questions related to their preferred payment method (traditional or smart contracts) and missing features or elements in the prototype.

The fourth phase included the TAM inspired topics related to rating the perceived usefulness, perceived ease of use and intention to use the data marketplace [68]. The topic of intention to use consisted of five questions, related to intention to: use the data marketplace for buying data privately and professionally, use the data marketplace for selling data privately and professionally and recommend the data marketplace to others. These questions used the 5-points Likert scale for the ratings. Additionally, the phase aslo had two open ended questions related to the need for a smart city data marketplace and suggestions of scenarios for using the data marketplace.

The expert evaluations were recorded with audio and video recordings, in addition to written notes. The participants received an information letter about the expert evaluations including a consent form to give permission to make recordings and write about their profiles, feedback and suggestions in the Master's thesis report. The slides for the entire interview guide for the expert evaluations can be found in appendix B.

Why: The expert evaluation interview method was chosen since it provide indept discussions and answers to predefined topics, in addition to followup questions. It was also chosen since it provides opinions and needs from potential expert

users of a data marketplace, as well as expert knowledge about smart contracts and decentralized applications. All of the expert evaluations from each iteration of expert evaluation tested the same version of the prototype, which made it easier to compare the evaluation in a systematic way and draw conclusions. Four of the experts also participated in an evaluation of the chosen research approaches for the research project EA modeling and customer journeys. This was done to provide expert opinions on the choice of approaches and help provide answers to RQ3 about if EA modeling and customer journeys can help support the planning and design of a data marketplace. The method was chosen since it is a good way to evaluate the prototype and the process. The use of a TAM inspired evaluation helped answer important questions related to acceptance of the data marketplace. Figure 3.3 shows the steps of the expert evaluations.
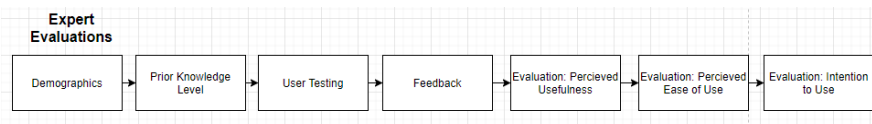
Figure 3.3: The steps of the expert evaluations.

3.4   Data Analysis Methods

What: The data analysis methods that were used in the master's thesis were qualitative analysis methods and was inspired by the Qualitative Content Analysis and Thematic Analysis[5] [69].

How: The recordings from the user testing and expert evaluation sessions were transcribed and the answers were registered in an excel table. There was a column for each participant and the answers were divided in rows based on the questions. Afterwards, the similar findings were grouped together by the following themes:

- Feedback and suggestions for improvements
- Preferred payment methods
- Missing features or elements
- Perceived usefulness
- Perceived ease of use
- Intention to buy data privately
- Intention to buy data professionally
- Intention to sell data privately
- Intention to sell data professionally
- Intention to recommend the data marketplace to others
- Need for a smart city data marketplace
- Scenarios for using the proposed data marketplace

Some questions in the expert evaluations used the 5-points Likert scale, which provided data for generating Radar diagrams. These diagrams were used to visu-

alize the different answers to the TAM evaluation questions[68]. There were also some open ended and followup questions in the evaluations. The answers to these questions were grouped based on similar themes and provided data for generating Spider diagrams (conceptual mind maps). These visual diagrams help organize concepts in a logical manner.

The systematic use of predefined questions made it easier to find trends and compare answers from different experts. The suggestions for improvements were evaluated and divided into the categories; must have or nice to have, future work or ready for design. This categorization made it easier to prioritise which suggestions should be future work or be designed in the next iterations.

Why: The qualitative data analysis method was chosen since it helps group the findings based on similar themes, which makes it easier to compare, understand and find trends and differences among the answers. The radar and spider diagrams were used to help show and compare the different answers in a visual and organized manner.

3.5   Structure of the Four Iterations

The project used an agile approach with four system design iterations. The color coding shows the four phases of the iterations. The blue color represents the "Requirement" phase which consists of the personas and requirement specification. The purple color represents the "Design Activities" phase which consists of the customer journeys and EA modeling. Further, the green color represents the "Prototype Design" phase which consists of the prototyping. Last but not least, the orange color represents the "Evaluation" phase which consists of the evaluation of the prototype and evaluation of EA modeling and customer journeys approaches.

The "Evaluation" phases of the iterations have slight differences. The "Evaluation" phase of the first and second iteration consisted of user testing of the prototype and evaluation of only the EA modeling approach. The "Evaluation" phase of the third and fourth iteration consisted of expert evaluations of the prototype and evaluations of both the EA modeling and customer journeys approaches. The next four chapters (4-7) describe the four iterations of the project. Figure 3.4 shows the different parts and phases of the iterations in the agile design.
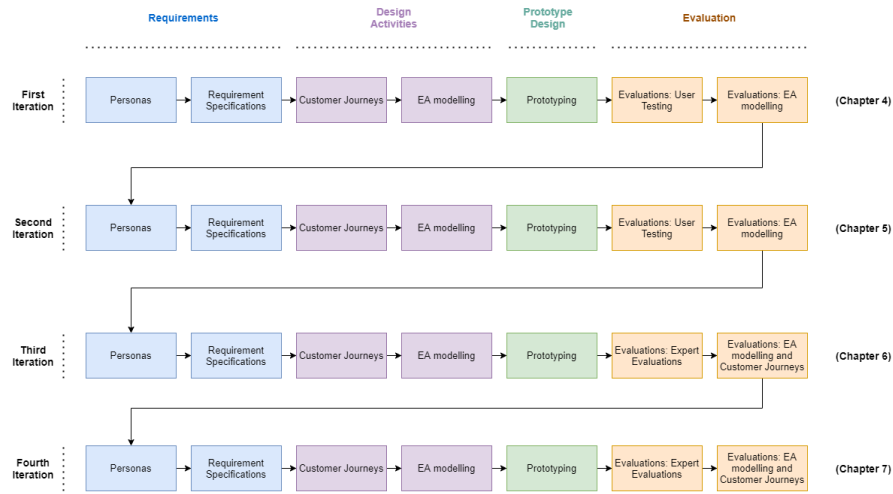
Figure 3.4: The figure shows the four system design iterations of the project and the corresponding chapters and color coded phases. The blue boxes represent the requirement phase, the purple represent the Design activities phase, the green represents the Prototype design phase and the orange represent the Evaluation phase of the iterations.

3.6 Summary

The chapter has described the research design, the research approach, the research methodology, data analysis methods and the structure of the four iterations.

Chapter 4

System Design: First Iteration

This chapter describes the first system design iteration. The subsections describe the personas, the initial requirements specification, the customer journeys, the EA model, the prototype design, the evaluation of the prototype and the evaluation of the EA modeling approach. Figure 4.1 shows the four color coded phases and the corresponding approaches used in the first iteration.
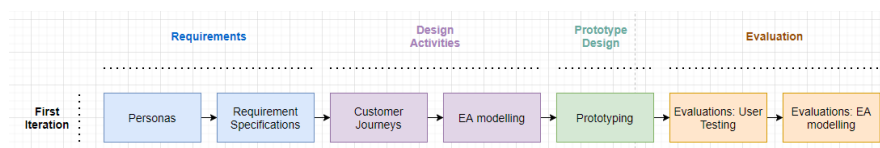
Figure 4.1: The four color coded phases and the flow of system design first iteration. The blue boxes represent the requirement phase, the purple represent the Design activities phase, the green represents the Prototype design phase and the orange represent the Evaluation phase of the iteration.

4.1 Requirements

This section covers the steps of the "Requirement" phase of the first iteration. It includes the initial interview with Trondheim municipality, the developed personas and the requirements specifications of the smart city data marketplace with functional and non-functional requirements.

4.1.1 Initial Interview with Trondheim Municipality

In the start of the project, a semi-structured interview was conducted with representatives from Trondheim municipality. The idea and the need for a data marketplace for the smart city Trondheim was discussed. The participants were interested in the idea and stated that there was a need for such a platform in Trondheim. They also showed an open mobility platform that was in progress in the municipality which also focus on sharing of data, specifically transport data. The master's

thesis supervisors had collaborated with Trondheim Municipality as partners in the +CityxChange project, and the need for a data marketplace for Trondheim were identified. This gave rise to the vision of a data marketplace for smart cities such as Trondheim. The meeting with Trondheim Municipality confirmed the need and relevance for the research project. Unfortunately there were no possibilities for further collaboration with Trondheim municipality for this master's thesis.

4.1.2 Personas

The user group of the smart city data marketplace was defined as people in the age group 20-70 years old who either wants to buy, sell, share and find data (including open data), get in contact with data sellers or all of the above. Three personas were developed to better understand the potential customers and use cases of the smart city data marketplace. They include personas with different use cases and experience with searching for data. Figure 4.2 shows the Personas step of the first iteration.
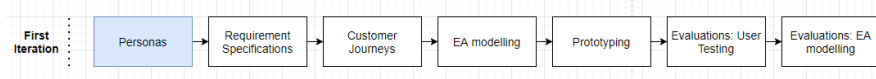
Figure 4.2: Personas, first iteration.

Persona 1 Lisa, 50 years old, researcher at SINTEF. She needs data about energy consumption in the Trondheim area. Lisa is used to searching for datasets and use open data portals. She is also used to analysing data of different file formats.

Figure 4.3: Persona 1, Icon from flaticon.com.

Persona 2 Martin, 45 years old, data analyst at Adresseavisa. He needs data about traffic in the Trondheim area. Martin is used to searching for datasets and analysing data of different file formats at work. He both sells and buys data (prosumer).

Figure 4.4: Persona 2, Icon from flaticon.com.

Persona 3 Ida, 25 years old, NTNU IT student, hobby data collector. She collects weather data from the Trondheim area with a hobby raspberry pi setup on her balcony. Ida has little prior knowledge with searching for or selling datasets.

Figure 4.5: Persona 3, Icon from flaticon.com.

4.1.3   Requirement Specification

This subsection include the functional and non-functional requirements for the first system design iteration. The requirements were specified based on findings from literature review, including best practices within web design and inspiration from background study of existing data marketplaces. There were no predefined functional or non-functional requirements for the data marketplace. Therefore one of the major tasks of the master's thesis was to investigate, plan and specify requirements for the smart city data marketplace. Figure 4.18 shows the requirement specification step of the first iteration.
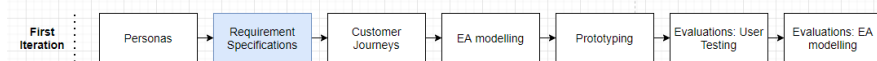
Figure 4.6: Requirement Specification, first iteration.

Functional Requirements

The requirements were defined and divided into must, should and may based on how important the different requirements are for the platform and for a minimum viable product of the smart city data marketplace. Table 4.1, 4.2 and 4.3 show the specified functional requirements for the smart city data marketplace for the first iteration.

Table 4.1: First Iteration Functional Requirements

ID	Must
FR1	Have a search data page, information dataset pages, an upload data page and a user profile page
FR2	Have functionality for filtering the search
FR3	Be scalable for many users and datasets

Table 4.2: First Iteration Functional Requirements

ID	Should
FR1	Be possible to find both open data and data for sale
FR2	Have a rating system for datasets
FR3	Be a decentralized marketplace
FR4	Have options for smart contracts
FR5	Have possibility to organize the view and filter on last updated, price and relevance for the results

Table 4.3: First Iteration Functional Requirements

ID	May
FR1	Have alternatives to use Smart city data marketplace tokens
FR2	Have incentives for using the data marketplace (i.e. get Smart city data marketplace SCDM tokens, buy one, get one free)

Non-Functional Requirements

The non-functional requirements involve the user experience of the data marketplace. Table 4.4 and 4.5 show the specified non-functional requirements of the first iteration.

Table 4.4: First Iteration Non-Functional Requirements

ID	Must
NFR1	Require few seconds to understand how to use the system
NFR2	Require few clicks to use the main functionalities (sell or buy data)
NFR3	Have good user experience

Table 4.5: First Iteration Non-Functional Requirements

ID	Should
NFR1	Use similar design as existing electronic marketplaces to make it familiar and easy to use
NFR2	Use colors and fonts that are easy to read
NFR3	Have information icons with explanations of difficult terms
NFR4	Have return buttons on every page for easy navigation
NFR5	Have possibility to organize the view on list or grid view

4.2 Design Activities

This section covers the steps of the "Design Activities" phase of the first iteration. It includes the developed customer journeys and EA model of the smart city data marketplace.

4.2.1 Service Design and Customer Journeys

This subsection includes the designed customer journeys for the first iteration. Figure 4.7 shows the customer journeys step of the first iteration.
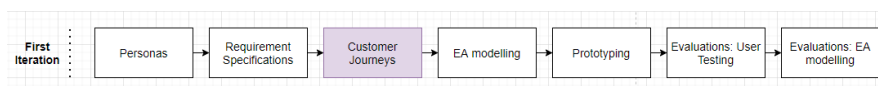
Figure 4.7: Customer Journeys, first iteration.

The customer journeys for the first iteration were developed for the most common and crucial functionalities of a data marketplace. They were based on the

findings from the literature review and background study of existing data market-place platforms. Figure 4.8, 4.9 and 4.10 show the developed customer journeys for the first system design iteration. They include the customer journeys for finding a free dataset, buying a dataset and uploading a dataset.
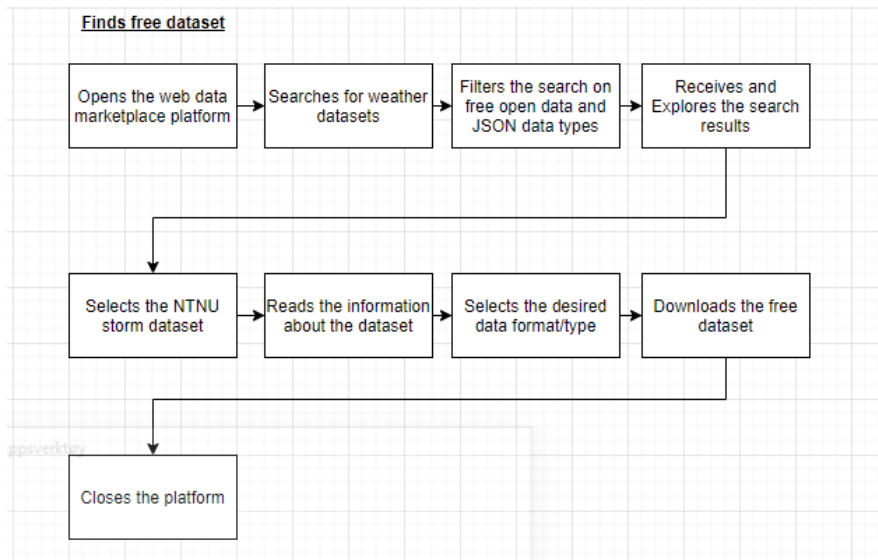
Figure 4.8: Customer journey of finding a free dataset, First Iteration.
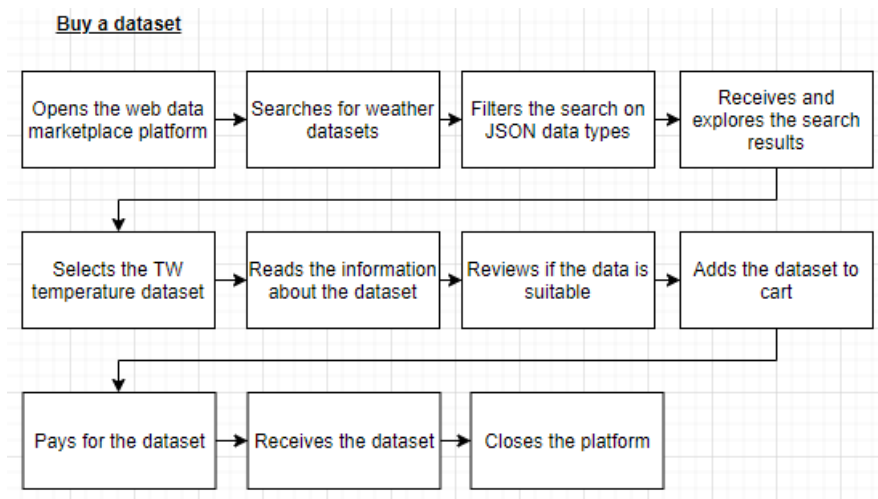
Figure 4.9: Customer journey of buying a dataset, First Iteration.
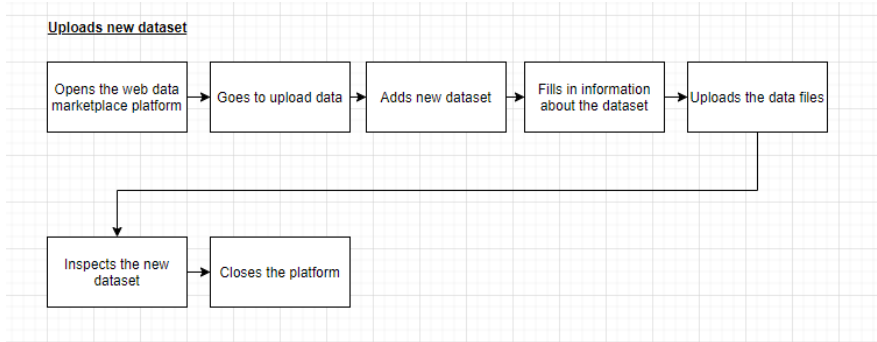
Figure 4.10: Customer journey of uploading a new dataset, First Iteration.

4.2.2 EA Modeling

This section includes the developed EA model for the data marketplace and explains the EA model layers and perspectives of the first iteration. Figure 4.11 shows the EA modeling step of the first iteration.
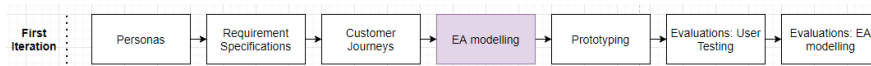
Figure 4.11: EA modeling, first iteration.

As mentioned in the Methods chapter 3, the project used the +CityxChange EA framework, specially since it has an extra focus on the data layer of a system which is relevant for a data marketplace. In this research project all the seven horizontal layers and two of the vertical perspectives of the framework were used to model the smart city data marketplace.

The developed EA model was based on findings from the literature review and uses components that are widely used in the studied data marketplaces and the state of the art aspects. Figure 4.12 shows the proposed EA model of the smart city data marketplace.
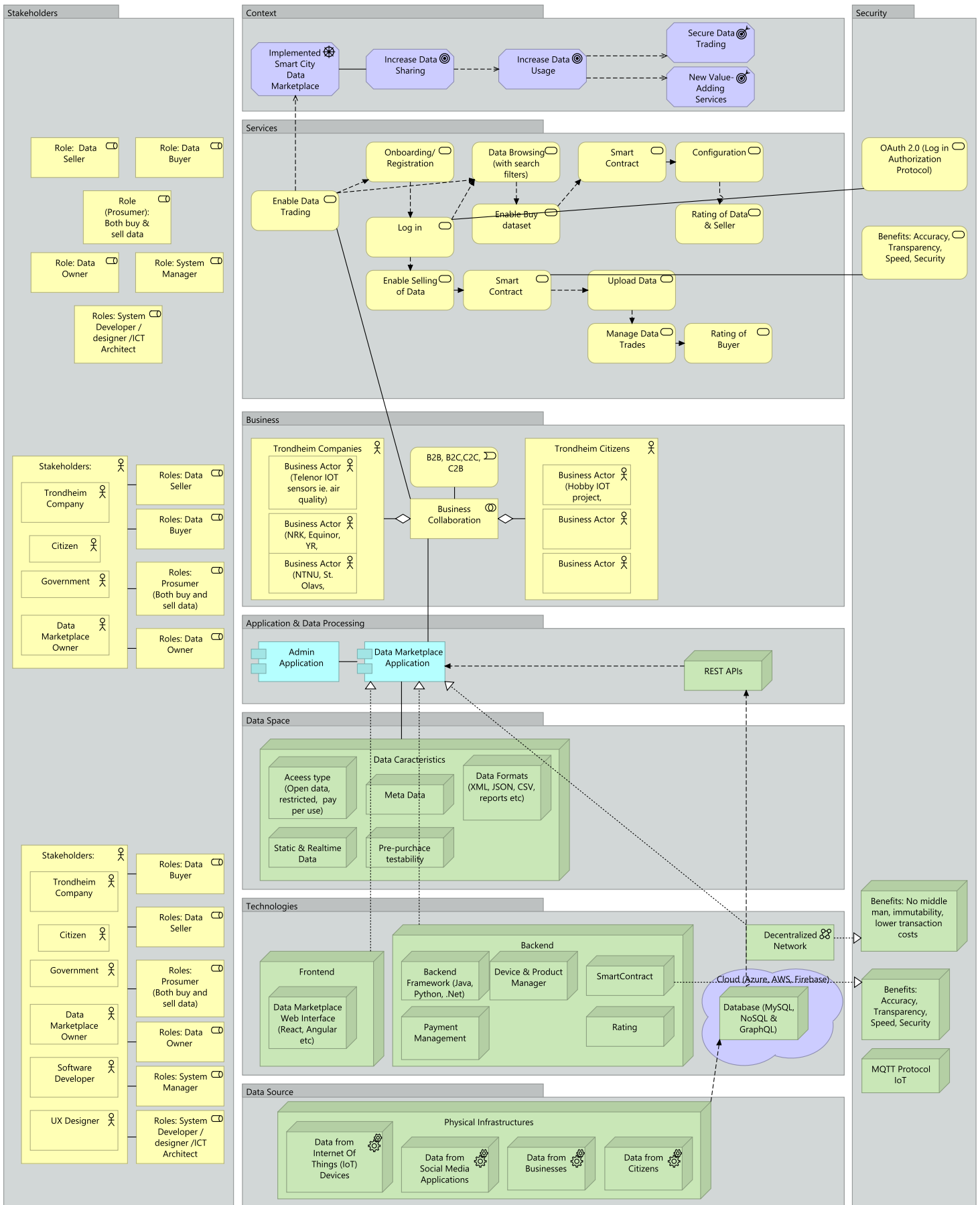
Figure 4.12: EA model of the Smart City Data Marketplace

Explanation of the EA Model Layers and Perspectives

The EA model consisted of the context layer, services layer, business layer, application layer, data space layer, technologies layer, data source layer and the security and the stakeholders perspectives.

    The context layer shows the goals of the smart city data marketplace. This is for instance to have an implemented data marketplace, to increase data usage,and data sharing, provide secure data trading.

    The services layer consists of the services in the data marketplace. It shows the most important services, such as register and login, search for a dataset, buy and rate a dataset, as well as upload a dataset and use smart contracts.

    The business layer shows the different business actors of the data marketplace and how they collaborate. It shows the different business models such as business to business (B2B) and business to customer (B2C). In this system there are both commercial companies and private persons who sell and buy data in the data marketplace.

    The application layer shows the applications that are related to the system, for example the data marketplace web application, the admin application and the APIs. Other relevant applications could be third party IoT applications to help manage data from IoT devices.

    The data space layer consists of the important data aspects, such as the metadata, file types (.XML, .PDF, .CSV etc.) and data types (dynamic or static). Additionally, it shows access types and the option for pre-purchase testability which is the option to test a part of the dataset before buying it. These data aspects are identified by the findings from the survey papers [8][9].

    The technologies layer consists of the technology stack of the system. The needs for a fullstack web application with frontend and backend are shown with possible technology choices, in addition to the choice of using a decentralized network type. It also shows the device and product management and the payment management. The inclusion of the decentralized network type was influenced by the numerous papers that showed this trend in the data trading landscape such as i3, Wibson and Datapace[14] [16] [15]. The technology stack is also inspired by the ICT architecture of the i3 system[14].

    The data source layer consists of the sources of the datasets that are traded in the marketplace. It shows that the smart city data marketplace has data from many sources, such as IoT devices (smart watches, smart home devices etc.), social media applications, business data and citizen data. The data sources of IoT sensors are relevant due to the abundance of IoT sensors in smart cities.

    The security perspective shows the security measures that are needed to make the data marketplace secure for the different layers of the EA model. The option to use smart contracts is one security aspect that was influenced by the trend towards decentralized data marketplaces in the literature [15] [14] [16].

    The stakeholders perspective shows the different stakeholders of the data marketplace such as the data buyer, data seller, data marketplace owner or ad-

ministrator and the citizens of the smart city. It also includes the prosumers who are users that both use the platform for buying and selling data.

Table 4.6 shows an overview of the different EA model layers and perspectives, and the corresponding papers that influenced the choice of components.

Table 4.6: First Iteration EA Model Layers and Perspectives and Related Papers

Layer/Perspective	Component	Reference
Context	The goals; increase data sharing and usage, implement a data marketplace which is easy to use to find, sell, buy and share data	[70]
Services	Rate data and seller, buy and sell data, search for data, filter search, register and login	[2] [9] [3]
Business	business actors, business models, B2B, B2C, C2B, C2C	[2] [47]
Applications	The web user interface, the admin application, the APIs	[14]
Data Space	Metadata, file types, access types, data types and pre-purchase testability	[8] [12]
Technologies	ICT architecture, fullstack web application with frontend, backend, cloud storage, smart contracts, decentralized network type, device, product and payment management	[14] [16] [15]
Data source	Data from IoT devices, social media applications, businesses and citizen	[28] [30]
Security	Decentralized network type, Smart contracts, identity verification, authorization, authentication	[14] [16] [15]
Stakeholders	Stakeholders; buyers, sellers, platform owners, administrators, citizens and prosumers	[8]

4.3 Prototype Design: First Iteration

This section covers the "Prototype Design" phase of the first iteration. It includes the proposed prototype with the descriptions of the design. Figure 4.13 shows the prototyping step of the first iteration.
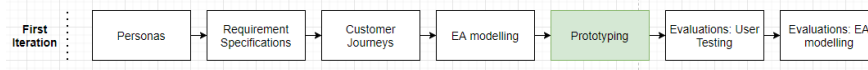
Figure 4.13: Design Prototyping, first iteration.

4.3.1 Descriptions of the Design

The first iteration involved a lot of fast prototyping with quick changes and improvements. Three main pages were identified for design based on findings from literature review and background study of existing platforms. The design was also based on the Personas, requirements specifications, customer journeys and EA model. The three pages were the buy data page, the search results page and the sell dataset page. These pages can be considered as the three main pages of a data marketplace.

In general many of the design choices were similar and inspired by popular electronic marketplaces. This was done intentionally since one of the goals were to make an intuitive user experience. It would be beneficial for the user experience and ease of use to have a design that is familiar for most customers. In this way the customer does not need to use much extra time to figure out how to use the platform. Additionally, the designers would not need to reinvent the wheel for what is considered good user experience and design.

Buy Data Page

On the "Buy Data" page shown in figure 4.14 there is a search bar for searching for datasets, a section for filtering the search on specific aspects and category buttons with symbols and names to quickly find datasets from a specific category. The chosen categories are domains that are often used for categorizing domains of smart cities. The use of category buttons is a normal way to display categories, and are used in many open data portals and electronic marketplaces such as Finn.no. The design was chosen since it visualizes the data categories in a neat and understandable way for the customer. There is also a "Recommended for you" section under the categories with some recommended datasets based on what you have searched for the most etc. The different datasets are displayed on a tile with information about the dataset, such as title, access type, data formats, price, rating, logo or image and a "See more"-button that redirects you to the specific dataset information page. An important design choice for the ease of use was to have both icons and text for most of the features to prevent misunderstanding and improve the user experience.

Filter Search Section

The filter search section on the "buy data"-page shows the filter options for the search. This include filters for data formats, price and access types which were influenced by the common aspects in the survey papers by Stahl et al. [8] [9] [2]. The use of common terms for the filters can make it more familiar for the customers, since the same terms are used in most data marketplaces.
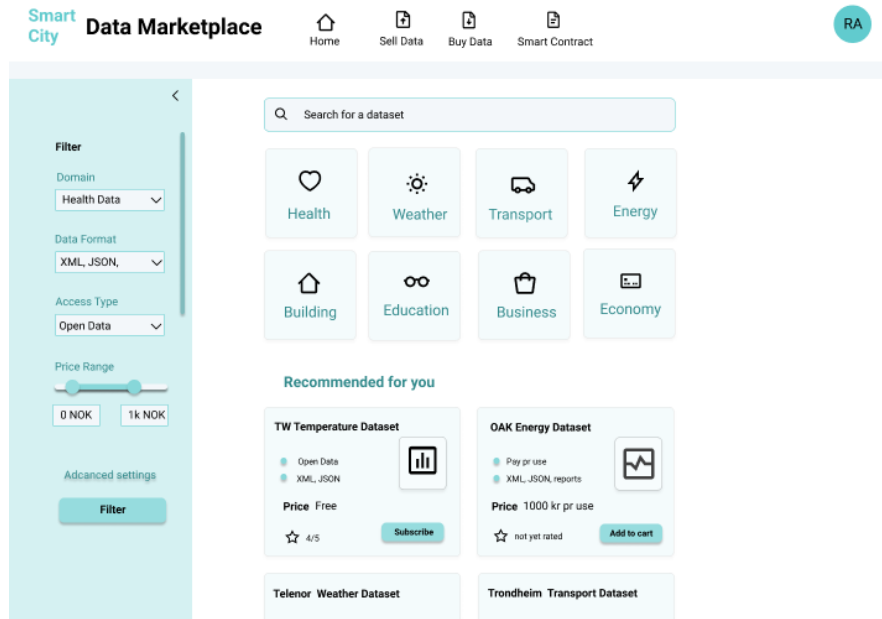
Figure 4.14: Screenshot of the buy dataset page, First Iteration, Figma prototype.

Search Results Page

The "search results" page shows the search results for the data marketplace which is similar to what you find in normal electronic marketplaces such as Finn.no or Ebay. Figure 4.15 shows the screenshot of the search results page.
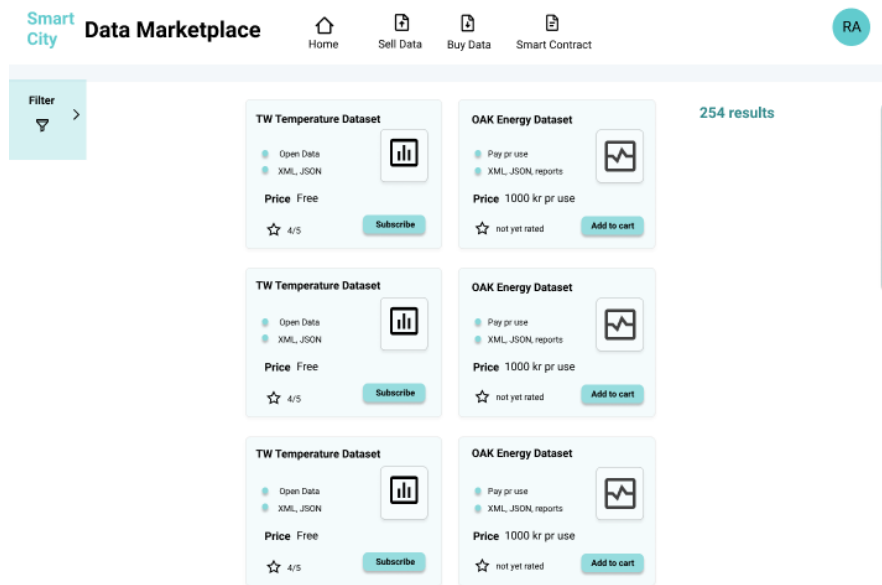
Figure 4.15: Screenshot of the search results page, First Iteration, Figma prototype.

Sell Data Page

The "sell data" page shows an overview of the datasets you have for sale and includes buttons for uploading a new dataset. There is one button for automatically retrieving information from a file and a button for registering the information manually. It also has a section with statistics for your sold datasets. This page use a very similar layout and design as the datapace prototype design [15] since it was used as a starting point for the design. Figure 4.16 shows the screenshot of the sell data page.
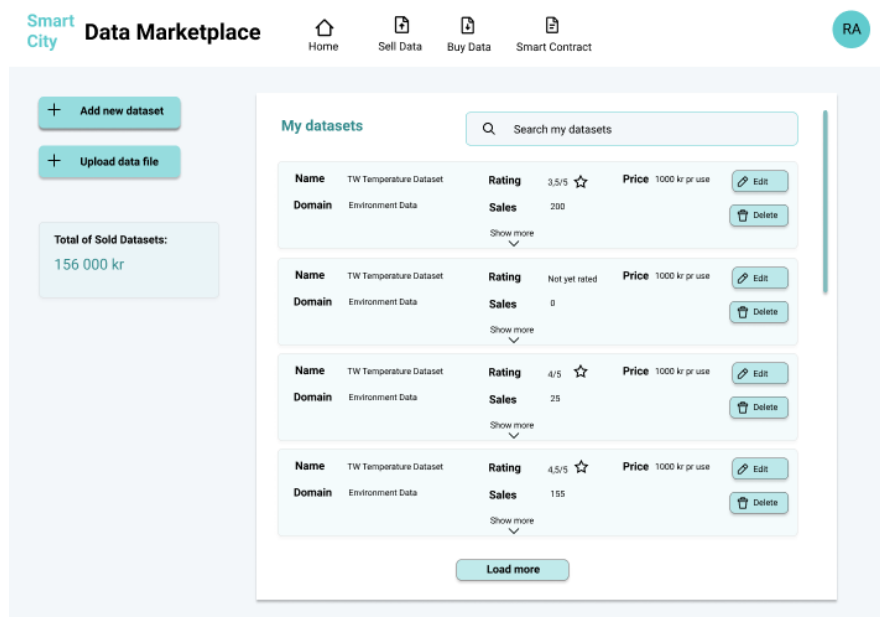
Figure 4.16: Screenshot of the sell dataset page, First Iteration, Figma prototype.

4.4 Evaluation

This section covers the steps of the "Evaluation" phase of the first iteration. It includes the user testing of the the smart city data marketplace prototype and the evaluations of the EA modeling approach. The evaluation in the first iteration worked as a pilot for the evaluations that were used in the next iterations.

4.4.1 First Iteration Evaluation: User Testing of Prototype

This subsection describes the user testing of the first iteration prototype. Figure 4.17 shows the user testing step in the first iteration.
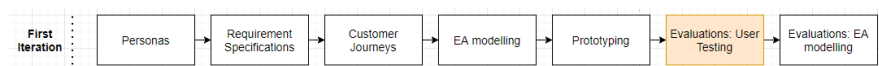
Figure 4.17: User Testing, first iteration.

There was conducted a 3 hours long user testing session to evaluate the proposed prototype and pilot the evaluation methods for the first design iteration. It resembled a co-creation session, since the tester provided many suggestions for design ideas and improvements for the prototype. Table 4.7 shows the demographics of the participant of the first iteration evaluations.

Table 4.7: First Iteration Demographics of Participants

ID	Age Group	Role	Company
UserTester1	20-29	Biologist	Åkerblå

Table 4.8 shows the user tester's answers to rating the prior knowledge level related to the topics data marketplaces, user testing, design prototyping and system development. The following 5-points Likert scale was used for evaluating the prior knowledge level of the participants: 1= Very low level, 2= low level, 3= neutral, 4= high level, 5= very high level.

Table 4.8: First Iteration Prior Knowledge Level of Participants

ID	Data Marketplace	User Testing	Design Prototyping	System Development
UserTester1	1	1	1	1

UserTester1 evaluated herself to have little prior experience with the topics, but she was relevant for the project since she is a potential customer of the smart city data marketplace.

Table 4.9 shows the user stories for the user testing of the prototype.

Table 4.9: First Iteration User Stories

ID	User Story	Comment
UserStory1	As a user you should find data related to weather and select the TW temperature sataset.	Suggestion for improvement
UserStory2	As a user you should filter your search on the JSON file type.	Suggestion for improvement
UserStory3	As a user you should upload a new dataset.	Suggestion for improvement

Table 4.10 shows the user tester's suggestions for improvements for the data marketplace prototype. Suggestion S1, S2 and S3 in table 4.10 were evaluated as a "Must have" for a high level of usefulness and ease of use for the platform. They were considered to be ready for design in the second iteration. Suggestion S4, S5

and S6 were evaluated as a "Nice to have" and were also considered to be ready for design in the second iteration. One of the suggestions (S4) was to change the search filter section to an Advanced settings link under the search bar. This was suggested since the filter section took up too much space on the page and was difficult to find when it was not expanded.

The tester liked the use of domain category buttons to navigate to the weather data, and that the dataset tile displayed info about the dataset without displaying too much information. UserTester1 did not understand what XML was and would like to have .XML instead to show that it was a file type. The menu text for "Buy data" and "Sell data" was a bit confusing for the tester, since it also was possible to find and upload free open data, not only buy and sell data. The texts could be renamed search data and upload data to cover both free open data and sold data. It was also suggested that the dataset rating should show how many people rated the dataset behind the rating.

Table 4.10: First Iteration User Testing Suggestions

ID	Suggestion	Review	Evaluated as
S1	Change the text from "Sell data" to "Upload data", and "Buy data" to "Search data" since you can both buy, sell and find open free data	Must have	Ready for design
S2	Add options for sorting the results by relevance etc.	Must have	Ready for design
S3	Add a dataset information page with info, ratings, map, tags, descriptions of the dataset	Must have	Ready for design
S4	Change the filter to a link under the search bar, since the old design takes up very much space on the page and is difficult to find when it is not expanded	Nice to have	Ready for design
S5	Change the file formats from XML to .XML to show that it is a file format and add number of ratings behind the rating in the dataset tiles in the search results page	Nice to have	Ready for design
S6	Add number of ratings behind the rating in the dataset tiles in the search results page	Nice to have	Ready for design

4.4.2 Evaluation of EA Model and EA Modeling Approach

This section describes the evaluation of the EA modeling approach in the first iteration. Figure 4.18 shows the evaluation of the EA modeling step of the iteration.
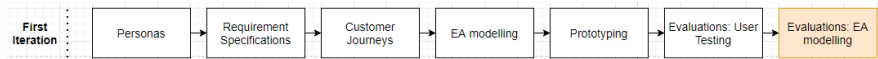
Figure 4.18: Evaluation of EA modeling approach, first iteration.

Firstly, the UserTester1 stated that the EA model was quite confusing, since it had very many boxes and arrows. She had no prior experience with EA or IT. Nevertheless, when she got some minutes to study the model it was easy for her to understand the system.

4.4.3 Retrospect of the First Iteration

The pilot of the evaluation methods showed positive and negative sides of the evaluation. It showed that it was important to make audio and video recordings of the evaluation sessions. The evaluation also showed that the user testing in the next evaluations should not last longer than 40 minutes. This was extra important to consider if there should be questions related to TAM and evaluations of the approaches in addition to the user testing.

4.5 Summary

This chapter has described the personas, the requirement specifications, the customer journeys and the EA model for the smart city data marketplace for the first system design iteration. It has also described the prototype design, the user testing and the evaluation of the EA modeling approach. The feedback from the evaluations of the first iteration will be used to formulate new or revised requirements for the development of the second iteration.

Chapter 5

System Design: Second Iteration

This chapter describes the second system design iteration. The subsections describe the personas, the updated requirements specification, the customer journeys, the EA model, the prototype design, the evaluation of the prototype and the evaluation of the EA modeling approach. Figure 5.1 shows the four color coded phases and the corresponding approaches used in the second iteration.
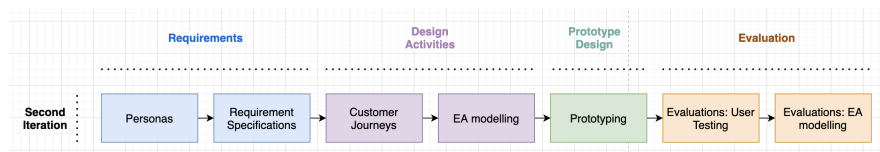
Figure 5.1: The four color coded phases and the flow of system design second iteration. The blue boxes represent the requirement phase, the purple represent the Design activities phase, the green represents the Prototype design phase and the orange represent the Evaluation phase of the iteration.

5.1 Requirements

This section covers the steps of the "Requirement" phase of the second iteration. It includes the input from the first iteration, the developed personas and updated requirements specifications. The functional and non-functional requirements were based on the feedback from the first iteration and findings from further literature review.

5.1.1 Input from First Iteration

The input from the first iteration was the user testing feedback and suggestions for improvements, in addition to the customer journeys, EA models, requirements and the proposed prototype design. The suggestions that were reviewed as ready for design were all the suggestions in table 4.10 in the first iteration chapter 4.

5.1.2 Personas

This section shows the new personas that were created for the second iteration. The two new personas were added since the initial personas of the first iteration did not include any personas with less technical skills. Figure 5.2 shows the personas step of the iteration.
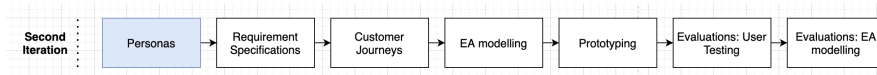
Figure 5.2: Personas, second iteration.

Persona 4 Per, 20 years old, NTNU Psychology student. He needs data for a statistics course assignment. Per has no prior experience with finding data and is not very technical.

Persona 5 Bjørn, 30 years old, entrepreneur. He is looking for data that can show possible opportunities for a start-up company in Trondheim. Bjørn is not very familiar with finding and analysing data. He wants to use data to make a startup that can provide new value-adding services for the smart city Trondheim.

5.1.3 Requirement Specification

This subsection includes the updated functional and non-functional requirements for the second system design iteration. These requirements were specified based on the user testing feedback from the first iteration and further literature review and background study of existing platforms. Figure 5.3 shows the requirement specification step of the second iteration.
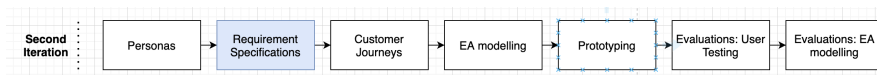
Figure 5.3: Requirement Specification, second iteration.

Functional Requirements

The requirements were updated, defined and divided into must, should and may based on how important the requirements were for the system and a minimum viable product of the data marketplace. Table 5.1, 5.2 and 5.3 show the specified functional requirements for the smart city data marketplace for the second iteration.

Table 5.1: Second Iteration Functional Requirements

ID	Must
FR1	Have a search data page, information dataset pages (with map, download test data), an upload data page, a user profile page
FR2	Have functionality for filtering the search
FR3	Be scalable for many users and datasets
FR4	Be a secure data marketplace

Table 5.2: Second Iteration Functional Requirements

ID	Should
FR1	Be possible to find both open data and pay per use or hour datasets
FR2	Have a rating system
FR3	Be a decentralized marketplace
FR4	Have options for smart contracts
FR5	Have possibility to organize the view and filter on last updated, price, relevance for the results

Table 5.3: Second Iteration Functional Requirements

ID	May
FR1	Have alternatives to use Smart city data marketplace tokens
FR2	Have incentives for using the data marketplace (i.e. get Smart city data marketplace SCDM tokens, buy one, get one free)

Non-Functional Requirements

The non-functional requirements were requirements that involve the user experience of the platform. Table 5.4 and 5.5 show the specified non-functional requirements of the platform in the second iteration.

Table 5.4: Second Iteration Non-Functional Requirements

ID	Must
NFR1	Be easy to understand
NFR2	Require few second to understand how to use the system
NFR3	Require few clicks to use the main functionalities (sell or buy data)
NFR4	Have good user experience

Table 5.5: Second Iteration Non-Functional Requirements

ID	Should
NFR1	Use similar design as existing electronic marketplaces to make it familiar and easy to use
NFR2	Use colors, contrasts and fonts that is easy to read
NFR3	Have information icons with explanations of difficult terms
NFR4	Have return buttons on every page for easy navigation
NFR5	Have possibility to organize the view on list or grid view

5.2 Design Activities

This section covers the steps of the "Design Activities" phase of the second iteration. It includes the developed customer journeys and EA model of the smart city data marketplace.

5.2.1 Service Design and Customer Journeys

This subsection includes the updated customer journeys for the second iteration. Figure 5.4 shows the customer journeys step of the iteration.

Figure 5.4: Customer Journeys, second iteration.

Figure 5.5 shows the updated customer journey for buying a dataset. The change includes a new option to download a test dataset before deciding to buy

the dataset or not.
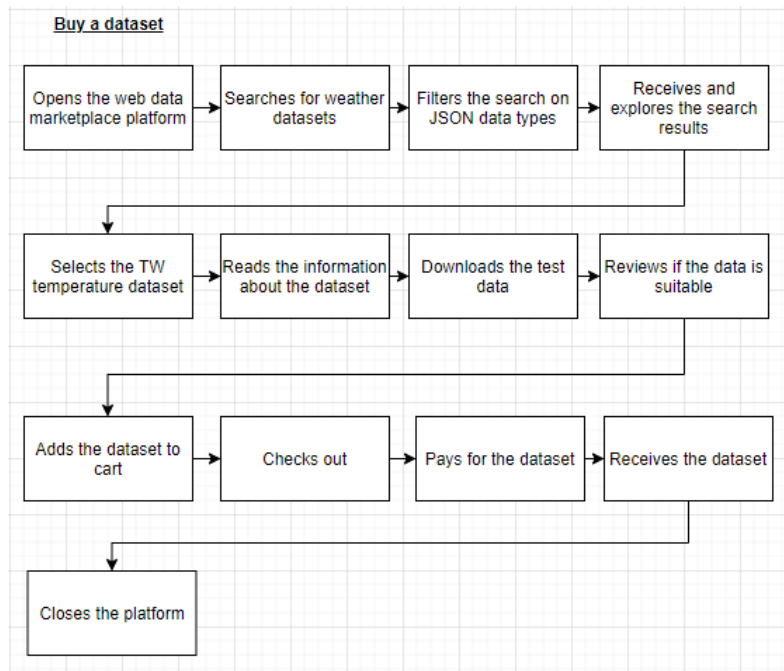
Figure 5.5: Customer journey of buying a dataset, Second Iteration.

5.2.2   EA Modeling

This section includes the updated EA model of the data marketplace for the second iteration. Figure 5.6 shows the EA modeling step of the iteration.
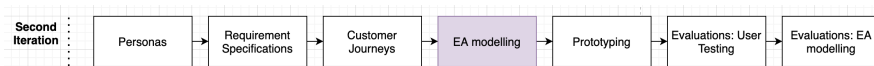
Figure 5.6: EA modeling, second iteration.

Figure 5.7 shows the updated service layer of the EA model for the second iteration.
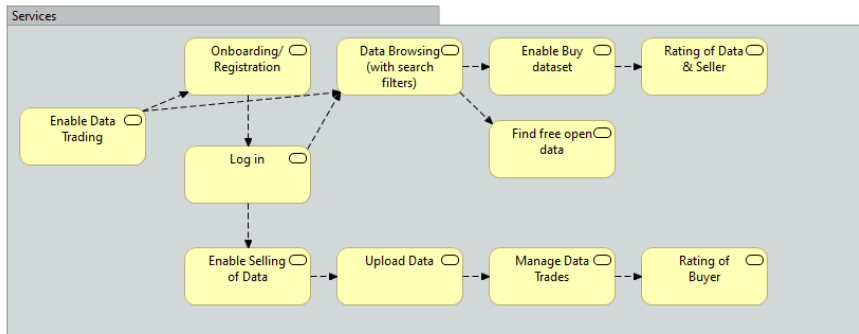
Figure 5.7: The updated services layer of the EA model, Second Iteration.

The service layer The change in the services layer consisted of adding a service for finding free open data.

5.3 Prototype Design: Second Iteration

This section covers the "Prototype Design" phase of the second iteration. It includes the prototype design with the changes, additions and descriptions of the design. Figure 5.8 shows the prototyping step of the iteration.

Figure 5.8: Prototype Design, second iteration.

The section reports the changes that were done to the prototype in the second iteration. The main changes were a new dataset information page, functionality to download a test dataset, the new color scheme, the new search filter design, the changes in the menu text from "Buy data" to "Search data" and "Sell data" to "Upload data", and links to "cart" and "help" page in the menu. The new changes and additions are shown in table 5.6 and 5.7. The changes and additions were influenced by the findings from further background study of existing platforms and suggestions and discussions from the user testing of the first iteration.

5.3.1 Descriptions of the Design

The color scheme of the design was changed to give the platform more contrast and make the components stand out more from the background. The color blue was chosen since it is a very popular color in digital design, which can provide a sense of familiarity for new users. Other changes included the new design of the search filter, the new names in the menu bar including links to "cart", "help" and new pages for information about specific datasets.

Search Data Page

Table 5.6: Second Iteration New Changes

ID	Changes
Change1	Changed the text in the menu from "Buy data" to "Search data" and "Sell data" to "Upload data" and changed the corresponding search icon, and removed the "Smart contract" in the menu bar
Change2	Changed the color scheme and added more contrast in the colors to make it easier to read
Change3	Changed the filter design to an "Advanced Settings"-link under the search bar which expands to a window with filters
Change4	Changed the "load more"-button to a numbered page navigation on the upload dataset page

Table 5.7: Second Iteration New Additions

ID	Additions
Addition1	Added sort by relevance etc
Addition2	Added number of datasets on the upload dataset page
Addition3	Added a dataset information page with info, price, data types, map, tags, ratings, "download test dataset"-button and "add to cart"-button
Addition4	Added number of ratings behind the rating
Addition5	Added .XML instead of just XML to show that it is a file format on the dataset tiles in the search results page
Addition6	Added "cart", "help" links and "logged in" in the menu bar

Figure 5.9 shows the screenshot of the search dataset page. It is very similar to the first iteration version, but does not have the filter search section on the side. Instead it has a link with "Advanced Settings" under the search bar that opens a popup page with search filters.
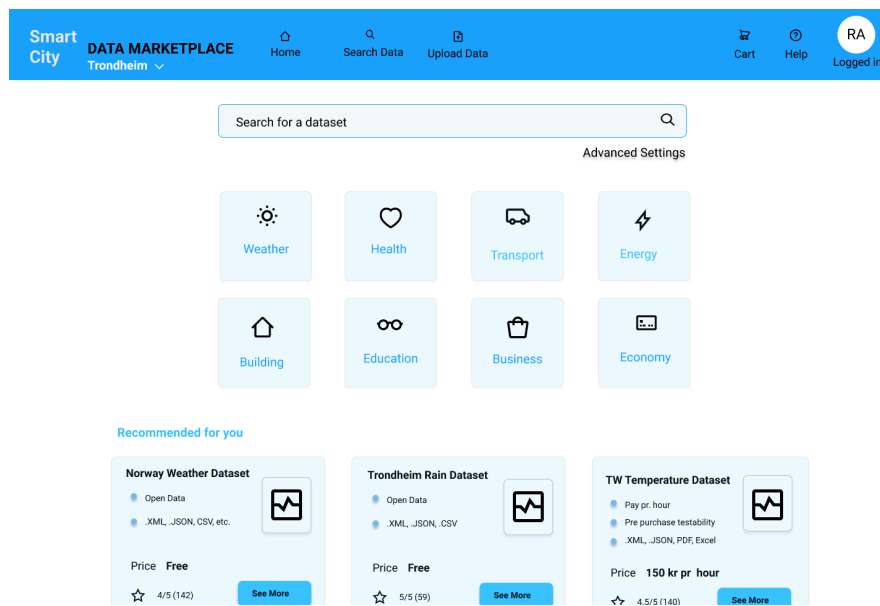
Figure 5.9: Screenshot of the search dataset page, Second Iteration, Figma prototype.

Advanced Settings

Figure 5.10 shows the screenshot of the advanced settings popup page. This page expands from the search bar when clicking the "Advanced settings" link. It includes the options to filter the search on "Domain", "Data Format", "Price Range" and "Access Type". There is a slider on the side to allow more filters if the number of data formats or domains grow. This ensures better scalability of the data marketplace platform design. There is also added an info icon next to terms that are not commonly known, to provide an explanation of the term before choosing the filter.
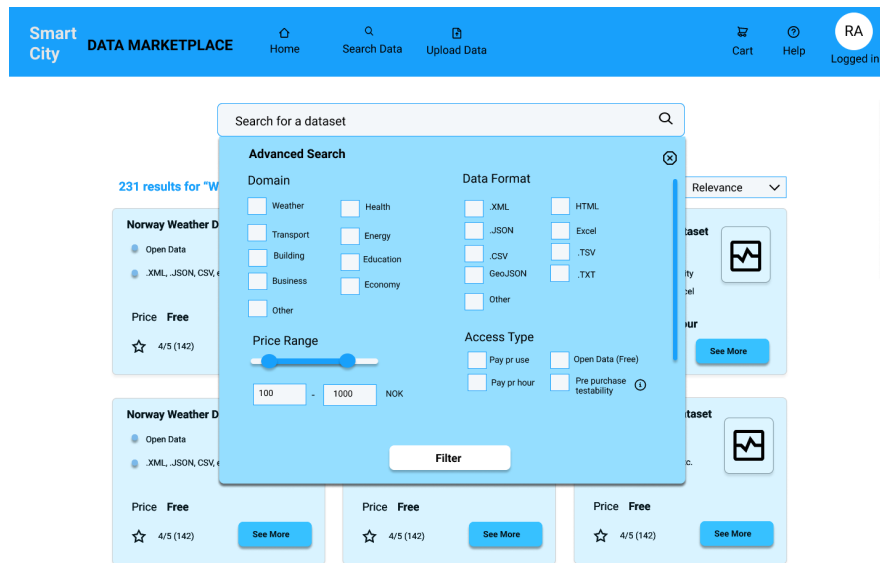
Figure 5.10: Screenshot of the advanced settings page, Second Iteration, Figma prototype.

Search Results Page

Figure 5.11 shows the screenshot of the results page. It consists of a search bar for searching for new datasets, advanced settings link for filtering the search, the number of results and tiles with info about the different datasets. It has also the option to filter the results on relevance, price, last updated etc. There are a numbered page navigation after the results to navigate to next or specific search result page.
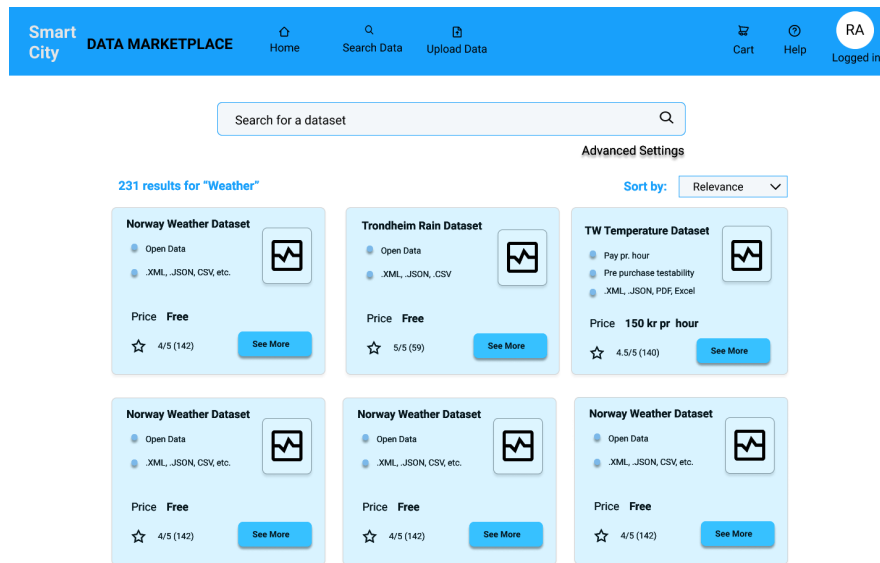
Figure 5.11: Screenshot of the search results page, Second Iteration, Figma prototype.

Dataset Information Page

Figure 5.12 shows the screenshot of the Dataset Information Page. It consists of information about a specific dataset. Here it is used mocked data to show a possible display of dataset information. The page includes information such as the rating, publisher, price, tags, map, logo, access type and data types of the dataset. It also include the possibility to download a test dataset which is important to help check the if the data fits the customer's own requirements. These aspects were chosen based on the identified common data aspects from the survey paper by Stahl et al. and Spiekermann et al. [8] [2].
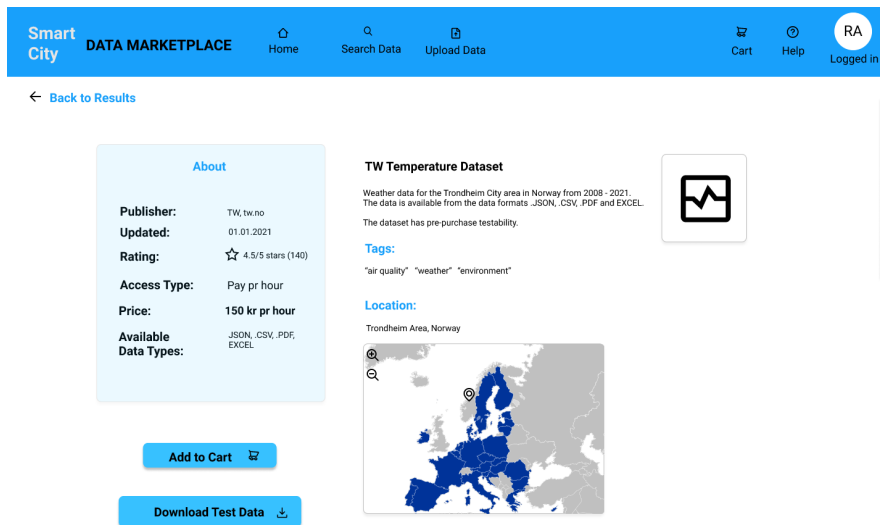
Figure 5.12: Screenshot of the dataset information page, Second Iteration, Figma prototype. Map from [71]

Upload New Data Page

Figure 5.12 shows the screenshot of the upload new data Page. This page did not change much from the first iteration other than the added number of datasets, and a numbered page navigation instead of the "load more"-button. This was done to make it more scalable and easier to navigate when the seller has many datasets for sale.
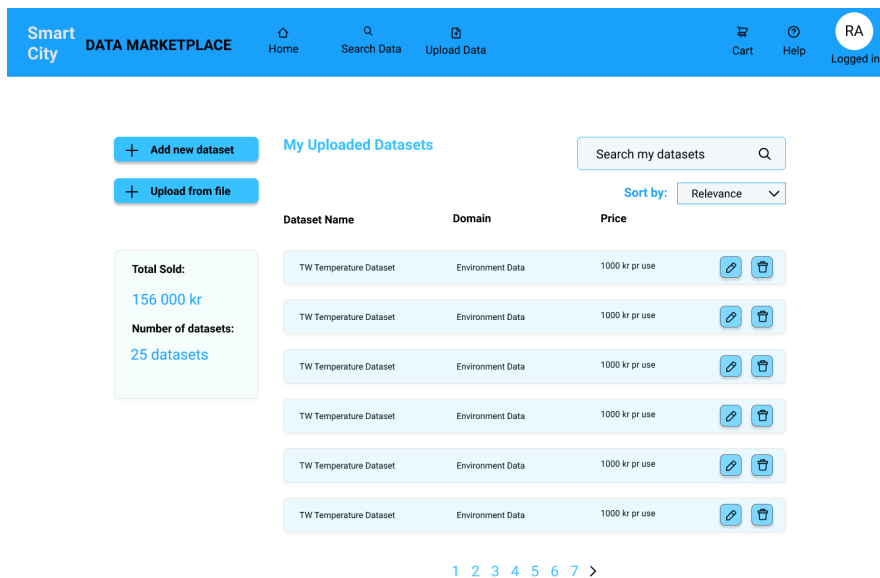
Figure 5.13: Screenshot of the upload dataset page, Second Iteration, Figma prototype.

The Menu Bar

The menu bar changed a lot from the first version. The "buy data" and "Sell data" texts were replaced by "Search data" and "upload data". These changes were based on user testing suggestions and feedback on confusion about the text. The links to Cart, Help and the "logged in" text that shows that you are already logged in were also added. This was inspired by popular electronic marketplaces and was included to make the user experience more familiar for the customers.

5.4 Evaluation

This section covers the steps of the "Evaluation" phase of the second iteration. It includes the user testing of the prototype and the evaluations of the EA modeling approach. The evaluations in the second iteration also worked as a pilot of the evaluations that should be used in the next iterations.

5.4.1 Second Iteration Evaluation: User Testing of Prototype

This section describes the evaluations of the second iteration. Figure 5.14 shows the user testing step in the iteration.

Figure 5.14: User Testing, second iteration.

There were conducted two 1 hours long user testing sessions to evaluate the prototype in the second design iteration. Table 5.8 shows the demographics of the participants for the user testing sessions.

Table 5.8: Second Iteration Demographics of Participants

ID	Age Group	Role	Company
UserTester2	20-29	Software Developer	TietoEvery
UserTester3	20-29	Cyber Security Student	NTNU

Table 5.9 shows the participants' answers to rating their prior knowledge level related to the topics data marketplaces, user testing, design prototyping and system development. The following 5-points Likert scale was used for evaluating the prior knowledge level of the participants: 1= Very low level, 2= low level, 3= neutral, 4= high level, 5= very high level.

The next part consisted of user testing of the data marketplace prototype. Table 5.10 shows the user stories for the user testing of the prototype in the second iteration.

Table 5.11 shows the participant's suggestions for improvements for the second iteration. Suggestions S1 and S4 were evaluated as "Must have" for a good quality

Table 5.9: Second Iteration Prior Knowledge Level of Participants

ID	Data Marketplace	User Testing	Design Prototyping	System Development
UserTester2	1	4	4	5
UserTester3	1	3	2	5

Table 5.10: Second Iteration User Stories

ID	User Story	Comment
UserStory1	As a user you should find data related to weather and select the TW Temperature Dataset.	No problems
UserStory2	As a user you should find the information about price, data types, access type and publisher for the TW Temperature Dataset.	Suggestions for improvements
UserStory3	As a user you should add the TW Temperature Dataset to cart and go to cart.	No problems
UserStory4	As a user you should filter your search on JSON file type.	No problems
UserStory5	As a user you should upload a new dataset.	Room for improvements

and usefulness of the platform. They were considered to be ready for design in the third iteration. Suggestions S2 and S3 were evaluated as "Nice to have" and ready for design in the next iteration.

Table 5.11: Second Iteration Suggestions for Improvements

ID	Suggestion	Review	Evaluated as
S1	Add information about the metadata and visualizations of the dataset	Must have	Ready for design
S2	Add a home page with intro to how to use the platform and statistics	Nice to have	Ready for design
S3	Add a forum page for discussions and tips	Nice to have	Ready for design
S4	Design the smart contract page	Must have	Ready for design

5.4.2 Evaluation of EA Model and EA Modeling Approach

This section describes the evaluation of the EA modeling approach in the second iteration. Figure 5.15 show the evaluation of the EA modeling approach step in

the iteration.
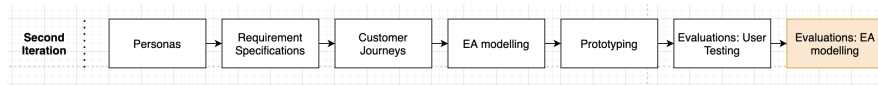
Figure 5.15: Evaluation of EA modeling approach, second iteration.

UserTester2 stated that the EA modeling approach was difficult to understand, but he also stated that "I can see the benefit of using EA to help technical and non-technical persons speak the same language".

UserTester3 liked the EA modeling approach and stated that it was very easy to understand and could be beneficial for her studies in cyber security, communication technologies and software development. She was used to developing UML diagrams etc and evaluated the EA modeling approach to be very useful for planning and designing the data marketplace. She also liked the tool Archi, since it seemed like a useful tool for making diagrams and was also free. She stated that the most useful parts of the EA model for planning and designing a prototype would be the services and the business layers in the EA model. If it should be used to implement the system, the technologies layer, the data space layer and the security perspective would also be very useful and important.

5.4.3 Retrospect of the Second Iteration

The test of the evaluation methods showed that it would be interesting to focus the evaluation on the EA modeling approach rather than the EA model or framework.

5.5 Summary

This chapter has described the updated personas, requirements, customer journeys and EA model for the second system design iteration. It has also described the prototype design, the user testing and the evaluation of the EA modeling approach. The feedback from the evaluations of the second iteration will be used to formulate new or revised requirements for the development of the third iteration.

Chapter 6

System Design: Third Iteration

This chapter describes the third system design iteration. The subsections describe the personas, the updated requirements specification, the customer journeys, the EA model, the prototype design, the expert evaluation of the prototype and the evaluation of the EA modeling and customer journeys approaches. Figure 6.1 shows the four color coded phases and the corresponding approaches used in the third iteration.
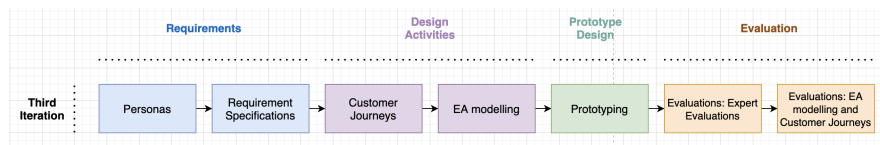
Figure 6.1: The four color coded phases and the flow of system design third iteration. The blue boxes represent the requirement phase, the purple represent the Design activities phase, the green represents the Prototype design phase and the orange represent the Evaluation phase of the iteration.

The chapter reports the changes that were done to the requirements specifications, customer journeys, EA model and prototype in the third iteration. The main changes in the iteration were the updated dataset information page, pages for home, forum, smart contract and register new dataset.

6.1 Requirements

This section covers the steps of the "Requirement" phase of the third iteration. It includes the input from the second iteration, the personas and updated requirement specifications. The with functional and non-functional requirements were based on the feedback from the second iteration and findings from further literature review.

6.1.1 Input from Second Iteration

The input from the second iteration was the user testing feedback and suggestions for improvements, in addition to the customer journeys, EA models, requirements and the proposed prototype design. The suggestions that were reviewed as ready for design were all the suggestions in table 4.10 in the second iteration chapter 5.

6.1.2 Requirement Specification

This subsections includes the functional and non-functional requirements for the third system design iteration. These requirements were specified based on the user testing feedback in the second iteration and findings from further literature review and background study of existing platforms. Figure 6.2 shows the requirement specification step of the iteration.
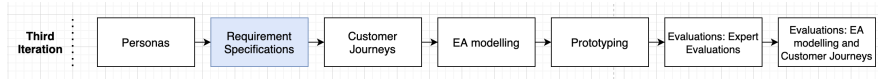
Figure 6.2: Requirement Specification, third iteration.

Functional Requirements

There were several changes and additions to the functional requirements in the third iteration based on findings from the user testing from the second iteration and literature review findings.

The changes include a home page that describe what you can do on the platform, some statistics about the data, news, success stories, a forum in the menu bar, a designed smart contract page, a registering a new dataset page and more information on the information dataset page with info about metadata, visualisations of the data, map and use cases. Tables 6.1, 6.2 and 6.3 show the updated functional requirements for the smart city data marketplace.

Non-Functional Requirements

There were no significant changes to the non-functional requirements in the third iteration.

6.2 Design Activities

This section covers the steps of the "Design Activities" phase of the third iteration. It includes the developed and updated customer journeys and EA model of the smart city data marketplace.

Table 6.1: Third Iteration Functional Requirements

ID	Must
FR1	Have a search data page, information dataset pages with information about metadata, visualizations, map, use cases, an upload data page, a registering a new dataset page, a user profile page, a cart page, a help page
FR2	Have functionality for filtering the search on price, pricing model, file format
FR3	Be scalable for many users and datasets
FR4	Be a secure data marketplace

Table 6.2: Third Iteration Functional Requirements

ID	Should
FR1	Be possible to find both open data and pay per use or hour datasets
FR2	Have a rating system
FR3	Be a decentralized marketplace
FR4	Have options for smart contracts
FR5	Have possibility to organize the view and filter the results by last updated, price, relevance for the results
FR6	Have a home page (with statistics, success stories, how to use the platform etc) and a forum page

Table 6.3: Third Iteration Functional Requirements

ID	May
FR1	Have alternatives to use Smart city data marketplace tokens
FR2	Have incentives for using the data marketplace, get Smart city data marketplace SCDM tokens, buy one, get one free

6.2.1 Service Design and Customer Journeys

This subsection includes the designed and updated customer journeys for the third iteration. Figure 6.3 shows the customer journeys step of the third iteration.
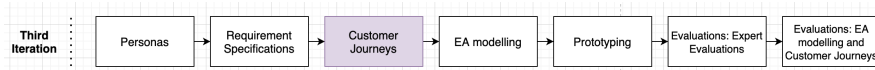
Figure 6.3: Customer Journeys, third iteration.

The customer journeys changed based on findings from more literature review with background study of existing data marketplaces and feedback from user testing. Figure 6.4 shows the updated customer journey for buying a dataset. The changes include more info available in the dataset information page such as metadata, use cases and visualizations to help evaluate the relevance of the dataset. It also includes the new option to select desired file types and the use of smart contract to pay for the dataset.
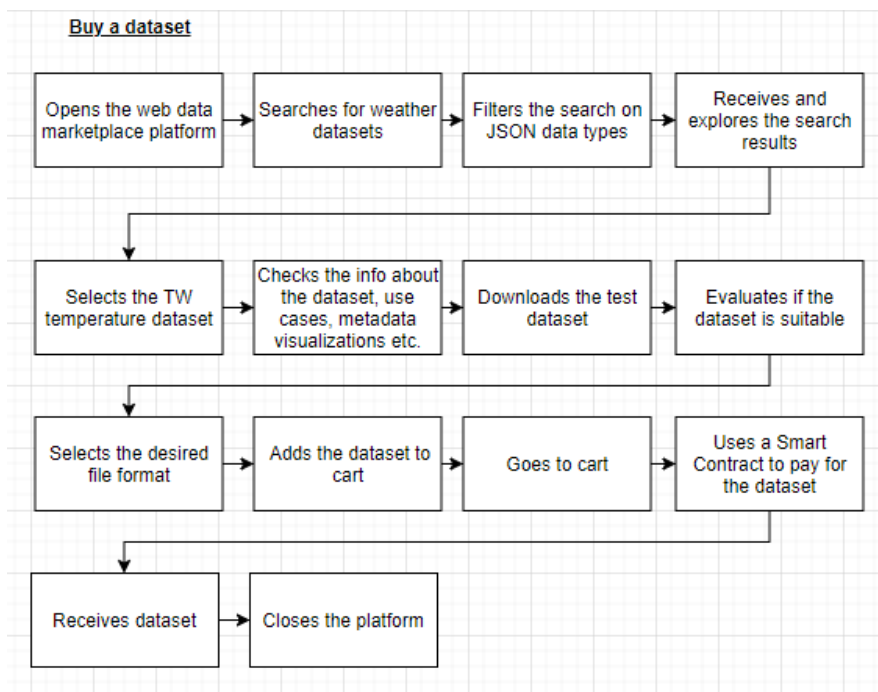
Figure 6.4: Customer journey of buying a dataset, Third Iteration.

6.2.2 EA Modeling

This section includes the updated EA model for the data marketplace, and describes the updated layers of the EA model for the third iteration. Figure 6.5 shows the EA modeling step of the iteration. The EA model was updated based on the new requirements for the third iteration.
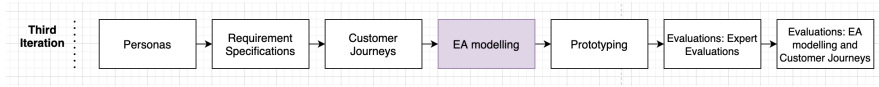
Figure 6.5: EA modeling, third iteration.
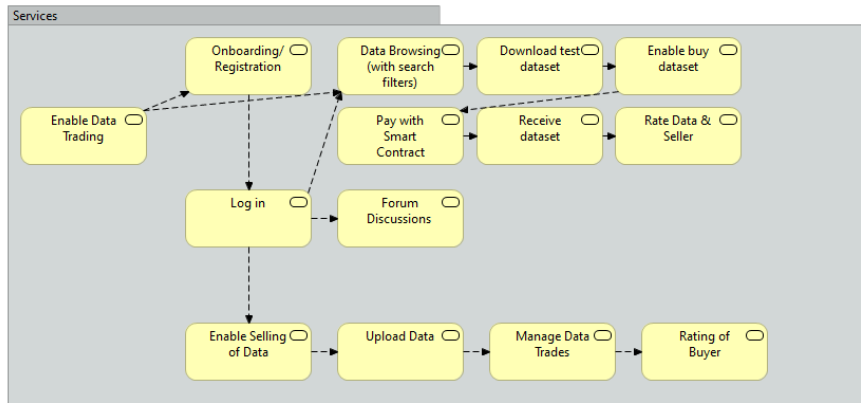
Figure 6.6: The updated services layer of the EA model, Third Iteration.

Services Layer

Figure 6.6 shows the updated services layer of the EA model. The services layer was changed by adding new services for using the new forum page and a service for using the smart contract to pay for the data. The forum page can be used to ask questions in addition to the help page.

6.3   Prototype Design: Third Iteration

This section covers the "Prototype Design" phase of the third iteration. It includes the prototype design with the changes, additions and the descriptions of the design. Figure 6.7 shows the prototyping step of the third iteration.
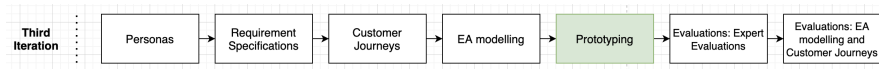
Figure 6.7: Design Prototyping, third iteration.

The new changes and additions in the third iteration are shown in table 6.4 and 6.5. They were influenced by the findings from further literature review, background study of existing platforms and suggestions and discussions from the previous user testing sessions.

Table 6.4: Third Iteration New Changes

ID	Changes
Change1	Changed the "Logged in" text to "My Profile" in the menu bar

Table 6.5: Third Iteration New Additions

ID	Additions
Addition1	Added a link to a forum page in the menu bar
Addition2	Designed a page for registering a new dataset
Addition3	Added a menu with tabs for info, metadata, visualizations, map and use cases on the information dataset page
Addition4	Added an option to select different smart cities in the menu bar
Addition5	Added option for selecting desired file types in the dataset information page
Addition6	Added a home page with statistics, introduction to what to do on the platform, success stories and new datasets
Addition7	Added a smart contract page with the information of the smart contract, a sign and pay button and an info box with explanation of smart contracts

6.3.1 Descriptions of the Design

The third iteration took the user testing feedback from the second iteration into account, and reviewed what was most important to design and compared it to findings from literature review and background study of existing platforms. The design of the upload dataset page, the search data page and the search results page did not change in the second iteration.

The design of the search data page did not change in the third iteration.

Home Page

Figure 6.8 shows the screenshot of the new home page. The design includes text to welcome the user and an introduction to what you can do on the platform. It also have boxes with statistics of the data marketplace, new datasets and success stories.
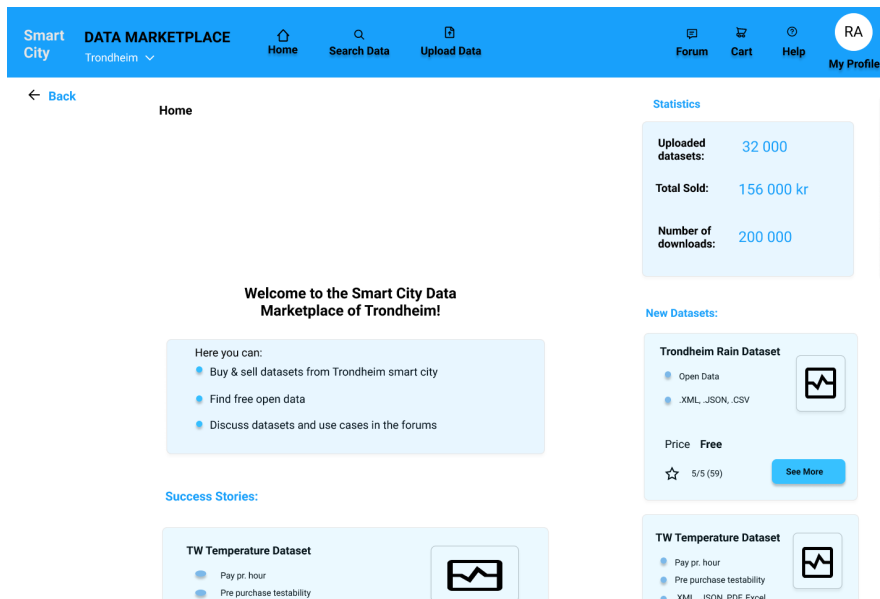
Figure 6.8: Screenshot of Home page, Third Iteration, Figma design prototype.
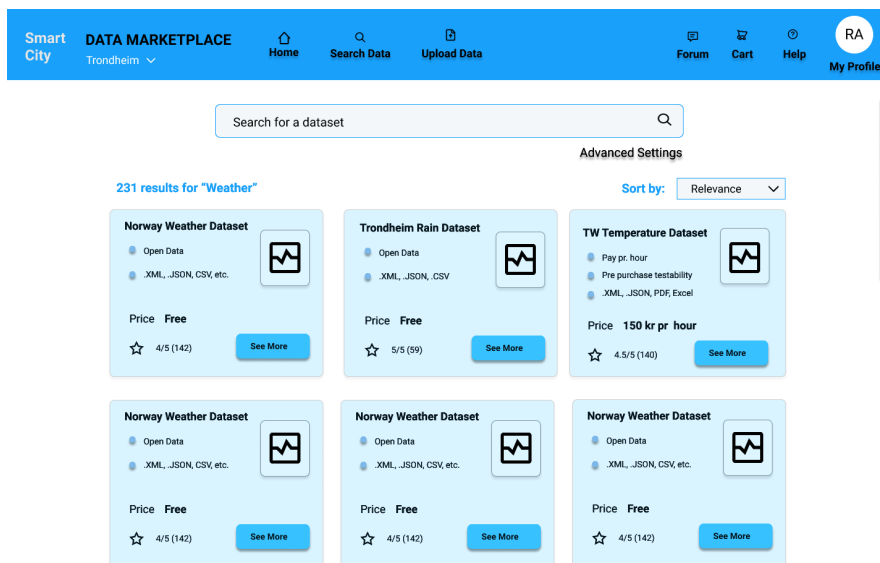
Figure 6.9: Screenshot of Search Results page, Third Iteration, Figma design prototype.

Dataset Information Page

Figure 6.10 shows the screenshot of the new dataset information page. The design was changed by adding menu with tabs for info about the dataset, metadata, visualizations, map and suggested use cases. It was also added an option for selecting desired file types in the dataset information page.
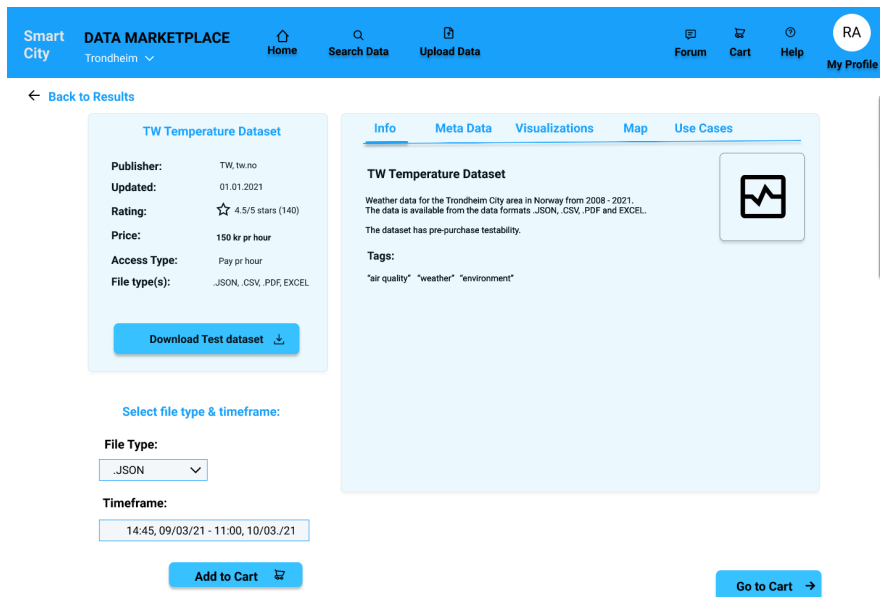
Figure 6.10: Screenshot of dataset information page, Third Iteration, Figma design prototype.

Smart Contract Page

Figure 6.11 shows the screenshot of the new smart contract page. The smart contract page was designed with the information of the smart contract, a sign and pay button and an info box with explanation of smart contracts.
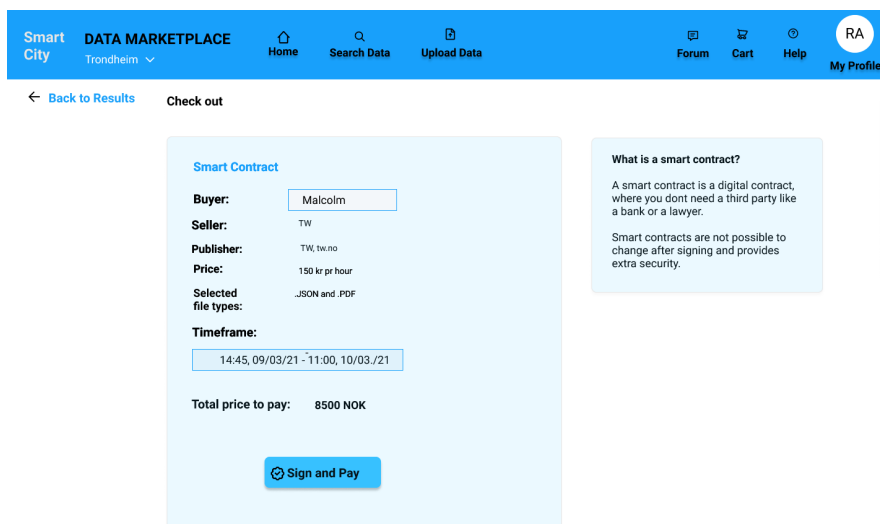
Figure 6.11: Screenshot of smart contract page, Third Iteration, Figma design prototype.

Register New Dataset Page

Figure 6.12 shows the screenshot of the register new dataset page. This page includes fields for registering the name of the dataset, the description, the access type, price, domain and upload a dataset file or files. The rest of the five pages for registering the dataset was not designed in the third iteration. The registration page used the same menu navigation as the information dataset page to make the design familiar and keep a read thread in the design.
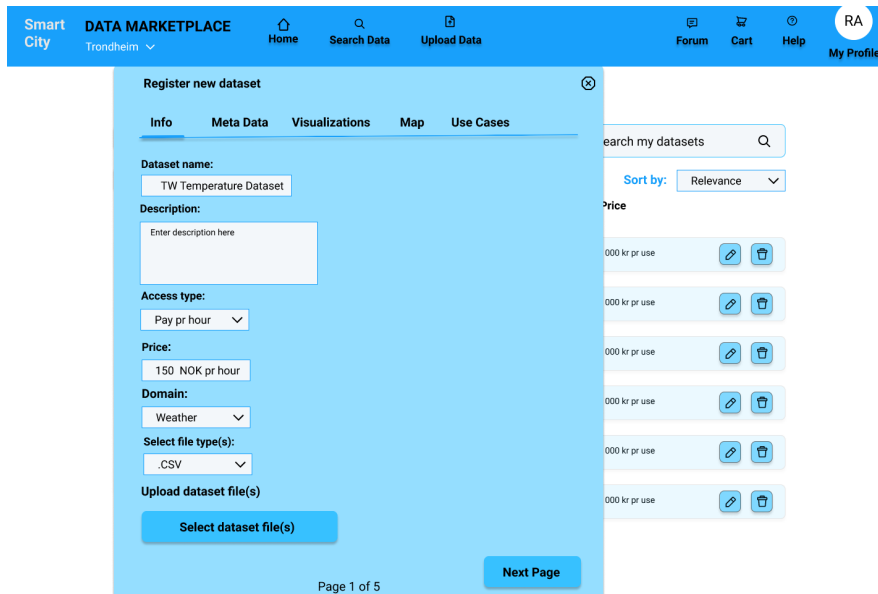
Figure 6.12: Screenshot of register new dataset page, Third Iteration, Figma design prototype.

Menu Bar

The link to the Forum page was added in the menu bar, but the page was not designed in the third iteration. An option to switch from Trondheim to an other Norwegian smart city was also added in the menu bar. This was designed to include data from several different smart cities in one common platform and facilitate for future expansion.

6.4 Evaluation

This section covers the steps of the "Evaluation" phase of the third iteration. It includes the expert evaluations of the the smart city data marketplace prototype and the evaluations of the EA modeling and customer journeys approaches.

6.4.1 Third Iteration Evaluation: Expert Evaluations

This section describes the expert evaluations of the third iteration. Figure 6.13 shows the expert evaluations step in the iteration.

Figure 6.13: Expert Evaluations, third iteration.

Figure 6.14 shows the seven parts of the expert evaluations.
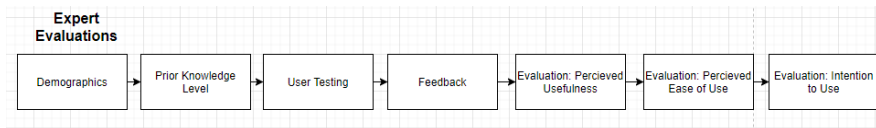
Figure 6.14: Illustration of the parts of the expert evaluations in the third iteration.

The section covers the expert profiles of the participants with demographics and prior knowledge level of relevant topics, the user stories and results from the user testing, the user testing feedback and suggestions for improvements and the TAM evaluations. The full description of the expert evaluation interview method can be found in the Methods chapter 3. The expert evaluations of the third iteration consisted of five separate sessions and were conducted for approximately 1-1,5 hours for each session.

Expert Profiles

The first part of the expert evaluations consisted of documenting expert profiles of the participants with demographics and prior knowledge level of central topics. Table 6.6 shows the demographics of the participants of the expert evaluations.

Table 6.6: Third Iteration Demographics of Participants

ID	Age Group	Role	Company
Expert1	20-29	PhD Candidate	NTNU
Expert2	40-49	System Architect	FourC
Expert3	40-49	Senior Researcher	NTNU
Expert4	40-49	Head of Technology Infrastructure	IOTA
Expert5	30-39	PhD Candidate	NTNU

Table 6.7 shows the experts' answers to rating their prior knowledge level of the topics data marketplaces, user testing, design prototyping and system development. The following 5-points Likert scale was used for evaluating the prior

knowledge level of the participants: 1= Very low level, 2= low level, 3= neutral, 4= high level, 5= very high level.

Table 6.7: Third Iteration Prior Knowledge Level of Participants

ID	Data Marketplace	User Testing	Design Prototyping	System Development
Expert1	2	2	2	2
Expert2	5	3	5	5
Expert3	3	4	4	4
Expert4	4	3	3	4
Expert5	3	5	3	4

User Testing

The next part consisted of user testing of the data marketplace prototype. Table 6.8 shows the user stories for the user testing of the prototype.

Table 6.8: Third Iteration User Stories

ID	User Story	Comment
UserStory1	As a user you should find data related to weather and select the TW Temperature Dataset.	No problems
UserStory2	As a user you should find the information about metadata, use cases and map for the TW Temperature Dataset.	Suggestions for improvements
UserStory3	As a user you should add the TW Temperature Dataset to cart and go to cart.	Suggested Improvements
UserStory4	As a user you should find the smart contract and sign it.	Suggested Improvements
UserStory5	As a user you should filter your search on JSON file type.	Some problems
UserStory6	As a user you should upload a new dataset.	Suggested Improvements
UserStory7	As a user you should go to the home page and find the success stories and statistics.	Suggested Improvements

Table 6.9 shows the experts' suggestions for improvements for the third iteration. Four of five experts stated that the "Upload from file"-button was confusing and that it probably was not needed on the register dataset page. Four of five experts also stated that they missed functionality to request a dataset, but this was also the only functionality they missed in data marketplace. One expert stated that

"The data marketplace is very easy to use, as easy as it can be". It was also stated that the data marketplace had a modern and intuitive design and very good user experience.

Most of the experts would choose traditional payment methods over smart contracts, but said it would be nice to have both options available specially for the future. Three of the experts were sceptical to crypto currencies in general.

Suggestions S1, S3, S4, S8 and S10 in table 6.9 were evaluated as "must have" to ensure a good quality and usefulness of the platform. They were considered to be ready for design in the fourth iteration. Suggestions S2, S6, S9 and S11 were evaluated as "nice to have" and ready for design in the fourth iteration. This evaluation were made since S2, S6, S9 and S11 would be beneficial for the user experience of the platform, but not the most crucial aspects of the platform. Suggestions S5, S7 and S12 were evaluated as "Nice to have" for future work. If it should be a fully implemented platform it would be nice to have implemented all the improvement suggestions.

Table 6.9: Third Iteration Expert Suggestions

ID	Suggestion	Review	Evaluated as
S1	Remove the "Upload from file"-button on the register dataset page	Must have	Ready for design
S2	Add options for requesting a dataset	Nice to have	Ready for design
S3	Add a preview of the dataset	Must have	Ready for design
S4	Change the pricing model since pay pr hour does not make sense	Must have	Ready for design
S5	Add more information on the home page	Nice to have	Future Work
S6	Have bullet points in stead of long sentences in the introduction to the data marketplace on the home page	Nice to have	Ready for design
S7	Have buttons for different views for buyer and seller in the menu bar	Nice to have	Future Work
S8	Change the text in the menu bar so it is easier to read	Must have	Ready for design
S9	Include links or integration of data from other data marketplaces	Nice to have	Ready for design
S10	Include fields for wallet address in the smart contract	Must have	Ready for design
S11	Include both traditional payment methods and smart contract	Nice to have	Ready for design
S12	Use stable coins as tokens in the data marketplace (as payment in the smart contract)	Nice to have	Future Work

Evaluations (TAM)

The next part consisted of evaluations inspired by the Technology Acceptance Model(TAM) that focused on the three aspects perceived usefulness, perceived ease of use and intention to use [68]. Table 6.10 shows the experts' answers to rating the perceived usefulness of the prototype, the perceived ease of use, the intention to use the data marketplace to buy data professionally, buy data privately, sell data professionally, sell data privately and to recommend the data marketplace to others. The following 5-points Likert scale was used for evaluating the usefulness and ease of use: 1= Very low level, 2= low level, 3= neutral, 4= high level, 5= very high level. The intention to use the data marketplace for buying and selling data, and recommending it to others used the following Likert scale: 1= Highly unlikely, 2= not likely, 3= neutral, 4= likely, 5= very likely.

Table 6.10: Third Iteration TAM Evaluations

ID	Usefulness	Ease of Use	Buy Profes-sionally	Buy Private	Sell Profes-sionally	Sell Private	Recommend to others
Expert1	5	5	5	2	5	5	5
Expert2	4	4	5	5	5	5	5
Expert3	3	4	2	1	1	3	3
Expert4	4	5	2	4	4	4	4
Expert5	4	5	5	4	5	4	4

Perceived Usefulness

The average rating for the usefulness of the smart city data marketplace prototype was a 4 (high level) of usefulness. The rating was given for the current version of prototype, and the experts stated that the usefulness would potentially be higher if the suggestions for improvements were done to the prototype in the next iterations.

Perceived Ease of use

The average rating for the ease of use of the prototype was 4.6, which means that is was close to very high level of ease of use.

Expert1 rated the ease of use of the prototype as very high level and stated that "I spent minimal time figuring out where to click, so it's as easy as it can get. Very intuitive and easy to use." The experts who rated the ease of use as 4, said that it was close to a five, but there were some room for improvements as listed in table 6.9.

Intention to Buy Data

The average rating for buying data professionally was 3.8 which indicates that it was likely that the experts would use the data marketplace to buy data for their work. On the other hand, the average rating for buying data privately was 3.2, which shows that it currently is less interest for buying data for private use.

Expert1 rated the intention to use the platform to buy data professionally was very high level and he stated that "At work it is very likely that I would buy data in the platform, but it really depends on whether there is a lot of good and relevant data or not". He rated the it as 2 for using the data marketplace for buying data privately, since he mostly did it through his work. Expert3 was generally more interested in open data and stated that he did not have time to buy data privately.

Intention to Sell Data

The average ratings for selling data both professionally and privately were 4, which indicates that there is a high will to use the data marketplace to sell data in general.

Expert1 stated that "This is ingenious if you want to sell data, it is probably more or less the only platform for selling your own data". He was very positive to selling data both privately and professionally in the data marketplace and rated it as very likely. Expert3 rated the using the platform to buy sell data professionally was not likely, since they make all data open, and rated 3 for sell privately since he did not have any data currently, but would sell it if he had any. Expert5 stated that he would use the data marketplace to sell his data privately, and that he had much agricultural data that could be sold. "I come from an agricultural country, so I would use this kind of data for my own. I have data, and everyone is working with data science nowadays. It is a good business for the future to have data and sell it".

Recommend to others

All the experts stated that they would recommend the data marketplace to others. The average rating was 4.2 which indicates a high willingness to recommend it to others. Expert1 stated that "In a context where you need data and are willing to pay for it, it's great, so I would absolutely recommend it". Expert3 rated likeliness to recommend it to others was neutral based on how the prototype were at the time, but higher if it would have more ways to check the quality of the data, etc. Expert5 stated that it would recommend the platform and "I would recommend it to others, since we are moving towards data, everything rely on data, the decisions and everything".

Need for a data marketplace for the Smart city Trondheim

All the experts stated that they saw a need for the data marketplace for Trondheim.

Expert1 stated that "In all the projects I have been involved in, there has been talk of how to exchange data in a decent way, with both researchers and industry actors, and many times the process was very difficult, so I see the need for this".Expert2 stated that it was a very high need for it in Trondheim and other smart cities. He stated that "In other places they need it even more than in Trondheim" Expert3 stated that it was a very high need for a smart city data marketplace with open data, and that "The open data is very much needed, we need data from the city for our own work". "It would be useful to have more data available and help solve the descoverabilty problem of finding where the data is, especially less known, smaller datasets. Expert4 stated that he saw a need for it, and that he

would start to build the platform for Trondheim, but also have data from other cities in Norway. Expert5 stated that there is a need for the smart city data marketplace and that he also liked the idea of a platform with data for all the smart cities in Trondheim. He stated that "There are lots of startups in Trondheim now, and the smart city is booming Trondheim. So there will be a need."

Scenarios where the Smart City Data Marketplace would be useful

The experts listed many scenarios where the smart city data marketplace would be useful. This include the following:

- Help researches with easy sharing of data in projects
- Help improve descoverability. There is much data available already, but it is not clear where it is.
- Help people find data related to energy consumption, smart city, renewable energy data, environmental data, IoT data, traffic data, number of passengers on the busses, historic data, satellite data, better map data etc.
- Help people sell data, since most people don't know where they can sell it. It makes it easier for others to find i too.

6.4.2   Evaluation of the EA modeling and Customer Journeys Approaches

This section describes the evaluation of the EA modeling and customer journeys approaches in the third iteration. Figure 6.15 shows the evaluation of the EA modeling and customer journeys approaches step in the iteration.

Figure 6.15: Evaluation of EA modeling and customer journeyers approaches, third iteration.

Expert2, Expert3, Expert4 and Expert5 also participated in the evaluations of the approaches. Table 6.11 shows the evaluation of the EA modeling and customer journeys approaches that were used in this research project. The following 5-points Likert scale was used for evaluating how easy it is to understand the approaches and the value of using EA modeling and customer journeys for planning and design of a data marketplace: 1= Very low level, 2= low level, 3= neutral, 4= high level, 5= very high level.

Table 6.11: Third Iteration Evaluation of EA Modeling and Customer Journeys Approaches

ID	Usefulness of EA modeling	Easy to understand EA modeling	Usefulness of customer journeys	Easy to understand Customer Journeys	Usefulness of combining both approaches
Expert2	5	5	5	5	5
Expert3	4	5	4	4	4
Expert4	2	2	5	5	3
Expert5	5	5	5	5	5

Expert2 was very positive to all the approaches, both using them together and separately and rated them as very high level of usefulness and level of easy to understand the approaches. He stated that "When making a prototype you need a toolbox, one thing is not enough, here you used EA and customer journeys, you probably used other approaches too informally. It is good to use different tools that help the design."

Expert3 rated the usefulness of the approaches for planning and designing the data marketplace as high level. He stated that "In his case it is both useful tools to think about what you want, and think about what you are solving".

Expert4 rated the usefulness and how easy EA modelling is to understand as low level. He stated "Overall for me EA modelling was not very useful, I would say it is a lost cause for me" and "it is not very easy to understand in my opinion". On the other hand he really liked customer journeys and thought they are very useful for developing prototypes and easy to understand. He was neutral to using the two approaches together for planning and designing the data marketplace.

Expert 5 was very positive to the use of both the approaches together and separately. He rated combining the two approaches as very high level of usefulness for the planning and design of the data marketplace. He stated that "They help each other to understand the system. Its better to use them together, it's good to do that. You need to see the overlapping between the steps".

Generally, the average rating for the use of combining the two approaches was high level of usefulness for helping the planning and design of the data marketplace. The majority of the experts rated the usefulness of the customer journeys as very high level. They stated that customer journeys are very important since they help visualize and plan the steps of the customer journeys in the platform and force the designer to think from a user's perspective.

6.4.3 Retrospect of the Third Iteration

The retrospect of the third iteration showed that the user testing part of the expert evaluations tended to take up very much time of the sessions. Therefore the next iteration evaluations were focused on being more strict about the time frame of

each part of the evaluations.

6.5   Summary

This chapter has described the updated requirements, customer journeys and EA model for the third system design iteration. It has also described the prototype design, the user testing and the evaluation of the EA modeling and customer journeys approaches. The feedback from the evaluations of the third iteration will be used to formulate new or revised requirements for the development of the fourth iteration.

Chapter 7

System Design: Fourth Iteration

This chapter describes the fourth system design iteration. The subsections describe the personas, the updated requirements specification, the customer journeys, the EA model, the prototype design, the expert evaluation of the prototype and the evaluation of the EA modelling and customer journeys approaches. Figure 7.1 shows the four color coded phases and the corresponding approaches used in the fourth iteration.
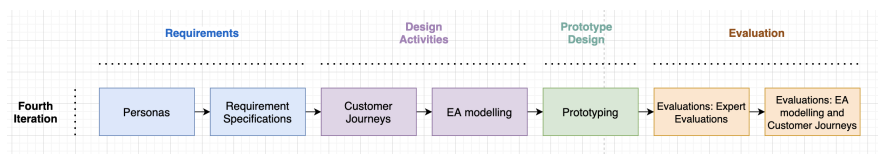
Figure 7.1: The four color coded phases and the flow of system design fourth iteration. The blue boxes represent the requirement phase, the purple represent the Design activities phase, the green represents the Prototype design phase and the orange represent the Evaluation phase of the iteration.

The chapter reports the changes that were done in the fourth iteration. The main changes in the iteration were the updated home page with more information, the updated navigation bar, the new design for the search filter, the new option for request a dataset, both real-time and static datasets examples, the new checkout page with both traditional payment methods and smart contract and the updated smart contract page and designed forum page.

7.1   Requirements

This section covers the steps of the "Requirement" phase of the fourth iteration. It includes the input from the third iteration, the developed personas and the updated requirements specifications. The functional and non-functional requirements were based on the feedback from the third iteration and further literature review.

7.1.1 Input from Third Iteration

The input from the third iteration was the suggested improvements from the expert evaluations, in addition to the updated EA models, customer journeys requirements and the designed prototype. The suggestions that were reviewed as ready for design in the fourth iteration were all the suggestions in table 6.9 in the third iteration chapter 6, besides S5, S7 and S12.

7.1.2 Requirement Specification

This subsection includes the functional and non-functional requirements for the fourth system design iteration. These requirements were specified based on the user testing feedback in the third iteration and findings from further literature review and background study of existing platforms. Figure 7.2 shows the requirement specification step of the iteration.
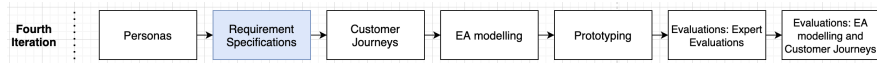
Figure 7.2: Requirement Specification, fourth iteration.

Functional Requirements

There were several changes and additions to the functional requirements in the iteration. These include new functionality like Request dataset, refer links to other data marketplaces and options for both traditional payment methods and smart contract. Tables 7.1, 7.2 and 7.3 show the updated functional requirements for the smart city data marketplace for the iteration.

Table 7.1: Fourth Iteration Functional Requirements

ID	Must
FR1	Have a search data page, information dataset pages (with information about metadata, visualizations, map, use cases), an upload data page, check out page, a registering a new dataset page, a user profile page, a cart page
FR2	Have functionality for filtering the search on price, pricing model, file format
FR3	Be scalable for many users and datasets
FR4	Be a secure data marketplace

Table 7.2: Fourth Iteration Functional Requirements

ID	Should
FR1	Be possible to find both open data and pay pr. usage, pr. dataset and pr. month for datasets
FR2	Have a review system
FR3	Be a semi decentralized marketplace
FR4	Have options for both smart contracts and traditional payment methods
FR5	Have possibility to organize the view on grid and list view, and filter the results by last updated, price, relevance for the results
FR6	Have a home page (with statistics, success stories, how to use the platform etc) and a forum page
FR7	Have functionality to request a new dataset and links to other data portals

Table 7.3: Fourth Iteration Functional Requirements

ID	May
FR1	Have alternatives to use Smart city data marketplace tokens
FR2	Have incentives for using the data marketplace, get SCDM tokens, buy one, get one free

Non-Functional Requirements

There were no significant changes to the non-functional requirements in the fourth iteration.

7.2 Design Activities

This section covers the steps of the "Design Activities" phase of the fourth iteration. It includes the updated customer journeys and EA model of the smart city data marketplace.

7.2.1 Service Design and Customer Journeys

This subsection includes the designed and updated customer journeys for the fourth iteration. Figure 7.3 shows the customer journeys step of the iteration.
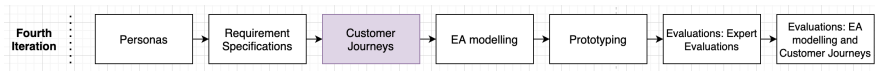
Figure 7.3: Customer Journeys, fourth iteration.

Figure 7.4 shows the updated customer journey for buying a dataset. It includes changed steps for checking out, selecting smart contracts or traditional payment methods, add wallet address for smart contracts and receive the data. Figure 7.5 and 7.6 show the two new customer journeys for requesting a dataset and using the forums.
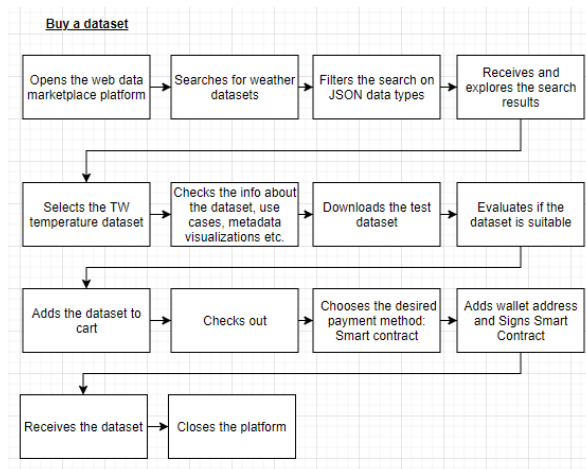
Figure 7.4: Customer journey of buying a dataset, Fourth Iteration.
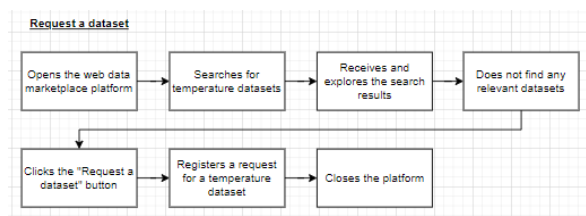
Figure 7.5: Customer journey of requesting a dataset, Fourth Iteration.
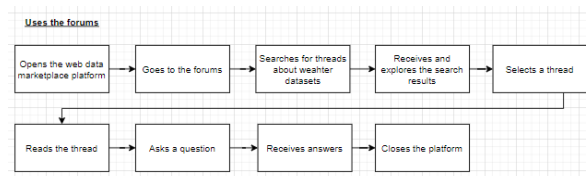
Figure 7.6: Customer journey of using the forums, Fourth Iteration.

7.2.2 EA Modeling

This section includes the explanations of the updated layers of the EA model for the fourth iteration. Figure 7.7 shows the EA modeling step of the iteration.
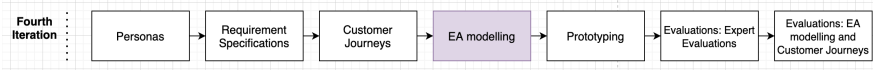
Figure 7.7: EA modeling, fourth iteration.

The EA model was updated based on the updated requirements for the iteration.

Services Layer

The services layer was changed by adding new services for using forum discussions and requesting a dataset. Additionally, the options for both paying with traditional fiat payment methods and crypto currencies with smart contracts were included. Figure 7.8 shows the updated services layer of the EA model.
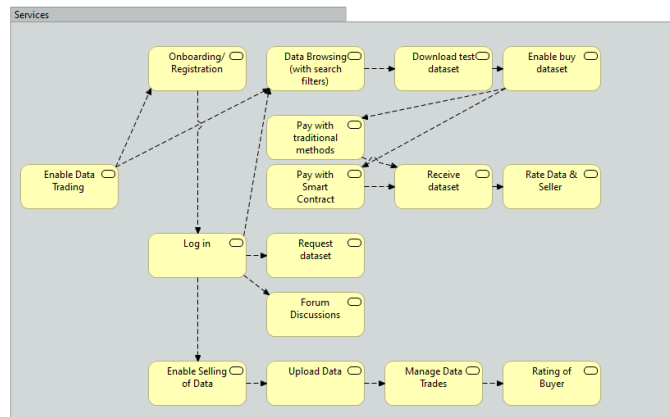
Figure 7.8: The updated Service Layer of the EA model, Fourth Iteration.

Technologies Layer

The change in the technologies layer included a changed network type from decentralized to semi-decentralized. The study of existing decentralized data marketplace prototypes such as i3 showed that the design and customer journeys would be more difficult and need more steps, if both the payment and the storage should be decentralized [14]. Therefore a partly decentralized data marketplace was the new choice, were the smart contract was the decentralized aspect and the data marketplace storage was kept centralized in the cloud.

7.3 Prototype Design: Fourth Iteration

This section covers the "Prototype Design" phase of the fourth iteration. It includes the prototype design with the changes, additions and the descriptions of

the design. The design for the fourth iteration is based on the requirements specifications, EA modeling and Customer Journeys. Figure 7.9 shows the prototyping step of the fourth iteration.
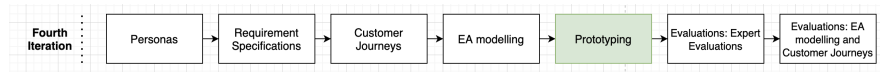
Figure 7.9: Design Prototyping, fourth iteration.

The new changes and additions in the fourth iteration are shown in table 7.4 and 7.5.

Table 7.4: Fourth Iteration New Changes

ID	Changes
Change1	Changed the text in the menu from "Search data" and "Upload data" to just "Search" and "Upload"
Change2	Changed from the text "Payment type" to "Pricing Model", "File format" to "File Type"
Change3	Changed the pricing models from "Pay pr. hour" to the three new options "Pay pr. dataset", "Pay pr. month (Subscription)" and "Pay pr. usage"
Change4	Changed the smart contract to include wallet address and Moonpay option
Change5	Changed position of info boxes on the Dataset Information page

Table 7.5: Fourth Iteration New Additions

ID	Additions
Addition1	Updated the page for registering a new dataset
Addition2	Added a new type of search filter design on the search result page
Addition3	Added button for request dataset on the search results page
Addition4	Added links to other data marketplaces
Addition5	Added check out page with overview and payment method options
Addition6	Added successful payment page with download dataset
Addition7	Added a section with preview of the dataset on the Dataset Information page
Addition8	Added a link to the sellers profile on the Dataset Information page, and a seller profile page
Addition9	Added three dots as "show more" domains on the search page
Addition10	Added a picture as the background for the menu bar

7.3.1 Descriptions of the Design

This subsection describes the design of the fourth iteration prototype.

Search Data Page

Figure 7.10 shows the screenshot of the updated search page. The changes here were to add three show more dots, to be able to add more domains later. This can help with scalability when there will be many datasets and domains.
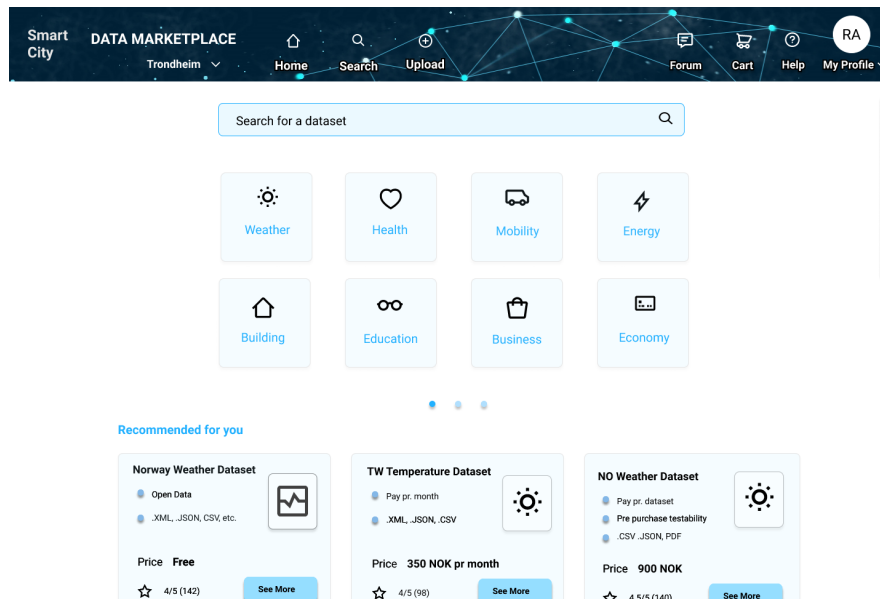
Figure 7.10: Screenshot of Search Data Page, Fourth Iteration, Figma design prototype.

Home Page

Figure 7.11 shows the screenshot of the updated home page. The design changed by replacing the info text with bullet points of the most important info to make it easier to read. Also a menu that is similar to the one used on the dataset information page was added. Here information tabs related to trending datasets, featured datasets, new datasets, most requested datasets and success stories were added. This type of menu is used as a red thread trough the whole platform, on both the dataset information page, the home page, the forum page and the register dataset page. This is done to make it easier for the user to navigate and recognize the same design throughout the whole platform.
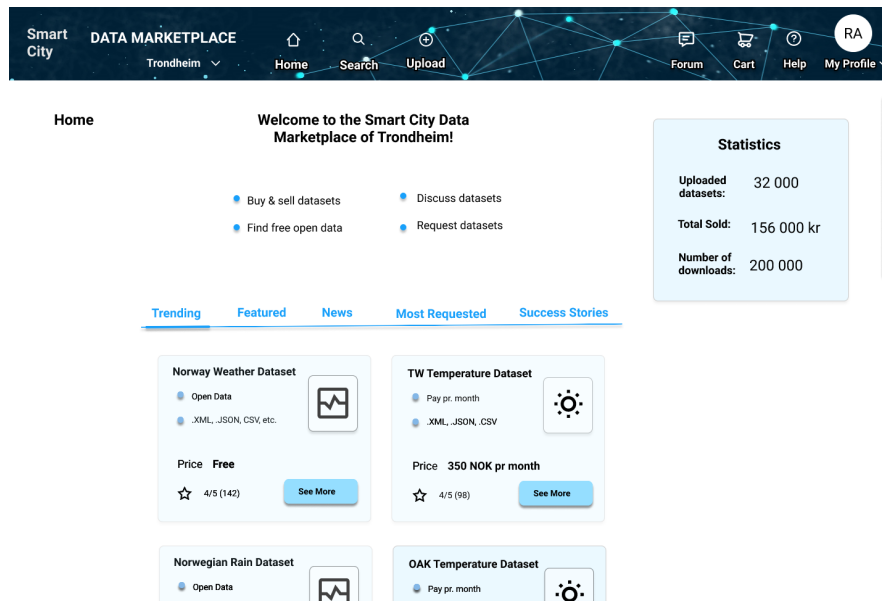
Figure 7.11: Screenshot of Home Page, Fourth Iteration, Figma design prototype.

Search Results Page

Figure 7.12 shows the screenshot of the updated search results page. It includes a new search filter design that was inspired by Airbnb. The user testing in the third iteration showed that it was difficult to find the filters when it was just a link with advanced settings for some testers. The new design was chosen since the filters are more accessible as buttons, since it makes the filters more visible to the users. It was also added a "More filters" button to make it possible to use and add more filters as the platform evolves.

There were also added options to organize the search results as list or grid view. The list view is good for scalabilty, since it makes it easier and more effective to go through many datasets. The page also include the text "Didn't find what you were looking for?" and a button with "Request a new dataset". Figure 7.13 shows a screenshot of the links to other data portals. Then request new dataset functionality was suggested and missed by 4 of 5 experts in the third iteration. The functionality for requesting a dataset was not found in the studied platforms, but it seems to be a valuable option to include.
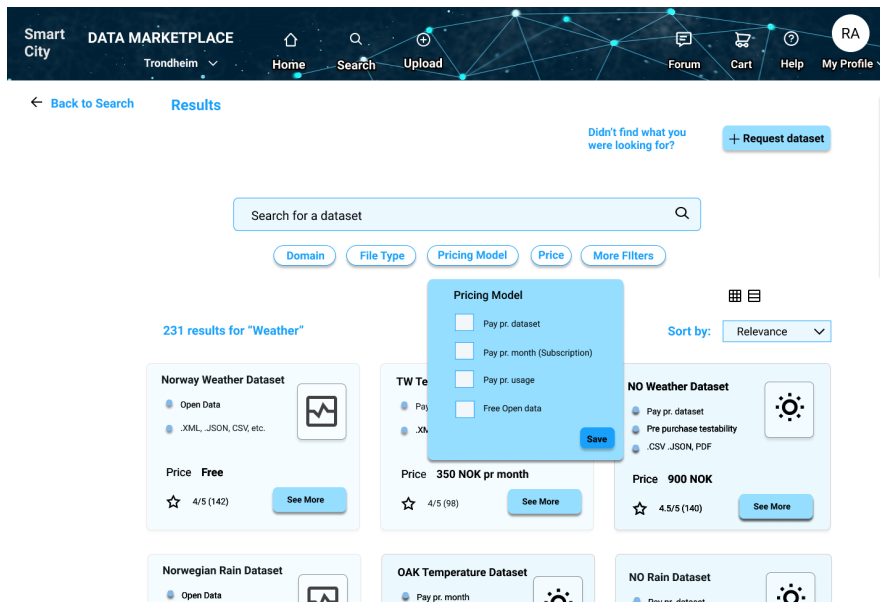
Figure 7.12: Screenshot of Search Results Page, Fourth Iteration, Figma design prototype.
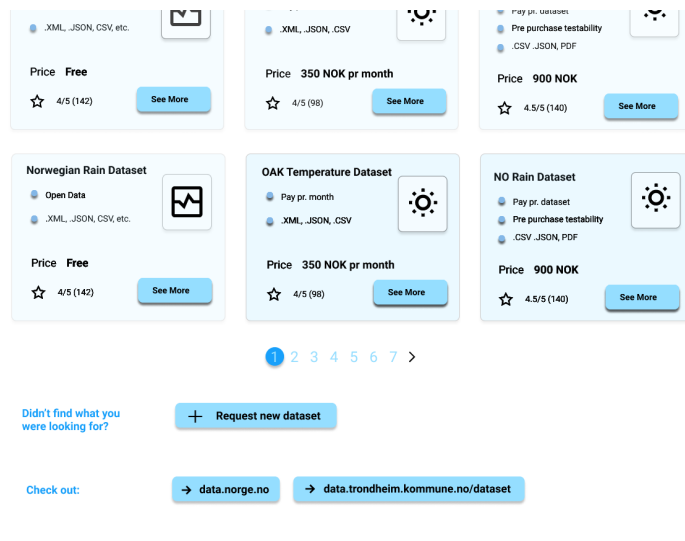
Figure 7.13: Screenshot of Search Results Page Links to other data portals, Fourth Iteration, Figma design prototype.

Dataset Information Page

Figure 7.14 shows the screenshot of the updated dataset information page. The design of the dataset information page was changed by switching the position of the info boxes. Words was also changed such as payment type to pricing model to fit better with the common terms in the data marketplace field. Datatype of

real-time data stream or static data was also added. This was added since it is very important information for making a decision on whether it fits the needs of the buyer or not. Seller contact information was also added to allow the buyers to contact the sellers. A sellers profile was also added since it is beneficial to see the other data the seller has to offer and to evaluate the quality and trustworthiness of the seller. Figure 7.15 and 7.16 show the tabs for the suggested use cases and the map for the dataset information page. The use cases tab also has a link to the forum discussions about the dataset.
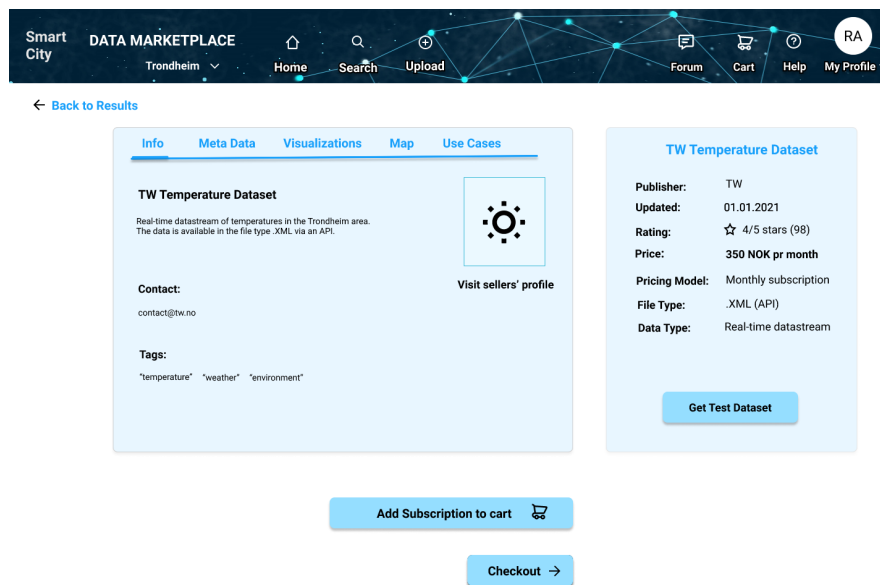
Figure 7.14: Screenshot of Dataset Information Page, Fourth Iteration, Figma design prototype.
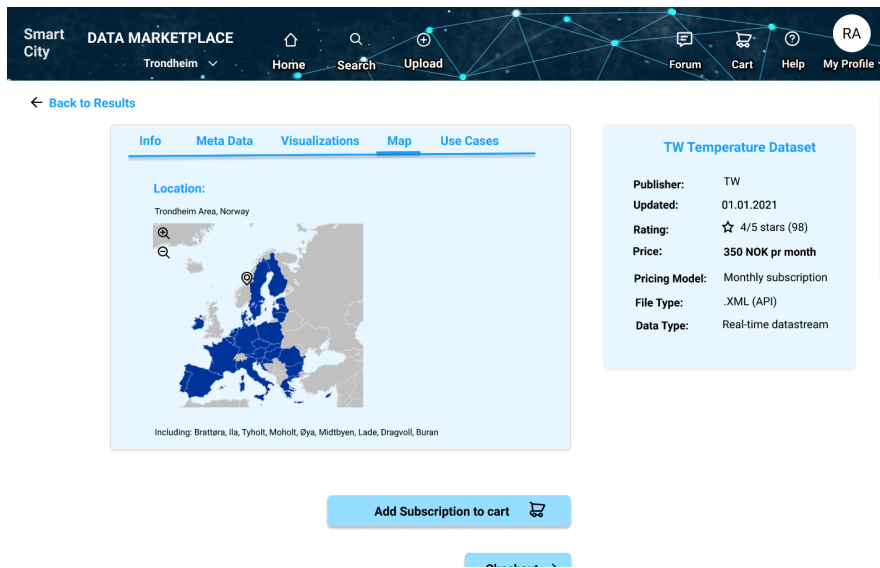
Figure 7.15: Screenshot of Dataset Information Page, Map tab, Fourth Iteration, Figma design prototype. Map from [71]
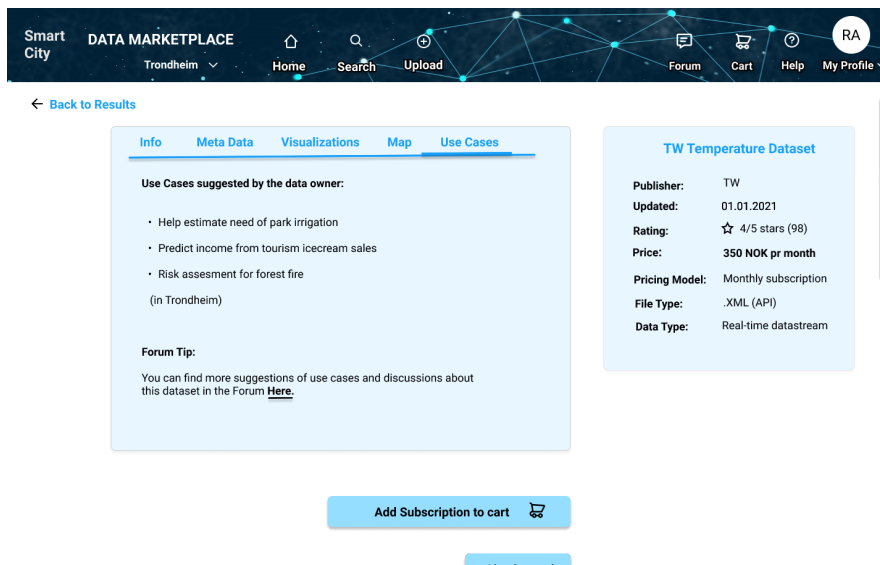
Figure 7.16: Screenshot of Dataset Information Page, Use Cases tab, Fourth Iteration, Figma design prototype.

Check Out Page

Figure 7.17 shows the screenshot of the new check out page. It includes an overview of the content in the cart and options for both tradition payment methods and smart contract (crypto currencies).
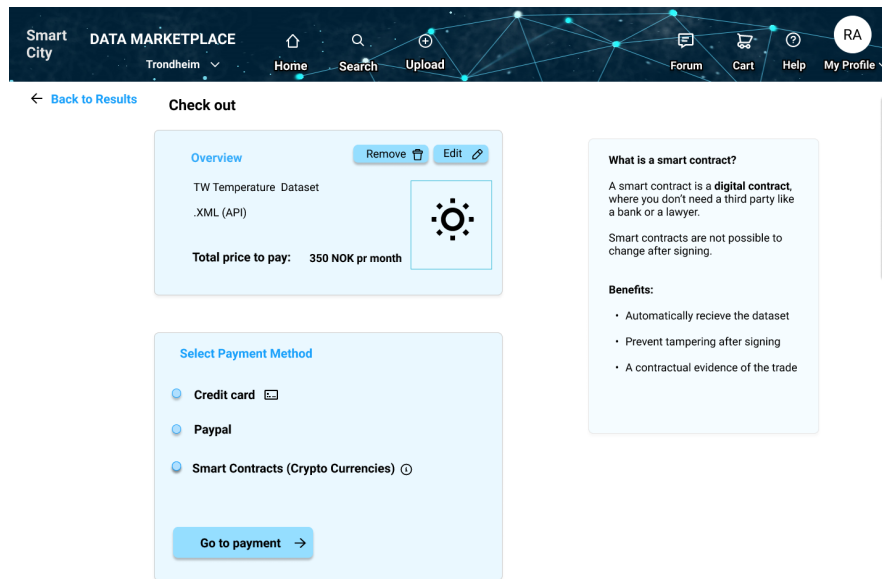
Figure 7.17: Screenshot of Check Out Page, Fourth Iteration, Figma design prototype.

Smart Contract Page

Figure 7.18 shows the screenshot of the updated smart contract page. The smart contract page was changed based on feedback from experts on crypto currencies and smart contracts. The suggestions were to add field for wallet address and have an option for using Moonpay[72]. The suggestion of using Moonpay was very interesting since it would allow users that don't have a wallet already to pay with crypto currencies. This would make it easier for people that is less familiar with crypto currencies to use the smart contract payment method.
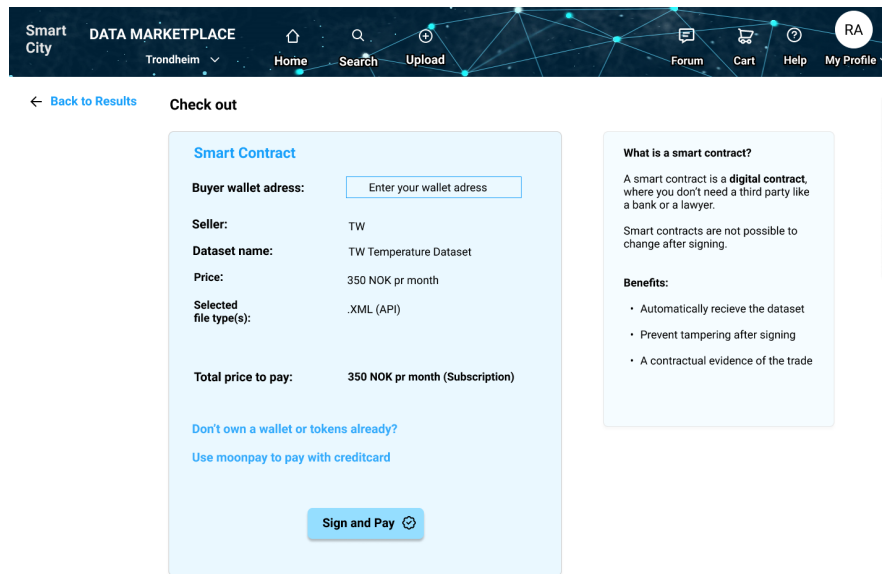
Figure 7.18: Screenshot of Smart Contract Page, Fourth Iteration, Figma design prototype.

Upload Dataset Page

Figure 7.19 shows the screenshot of the updated upload dataset page. The change included removing the "Upload from file" button, based on feedback from the experts. The majority of the testers stated that it was not necessary and more confusing to have both "Register a new dataset" and "Upload from file". Therefore the button was removed.
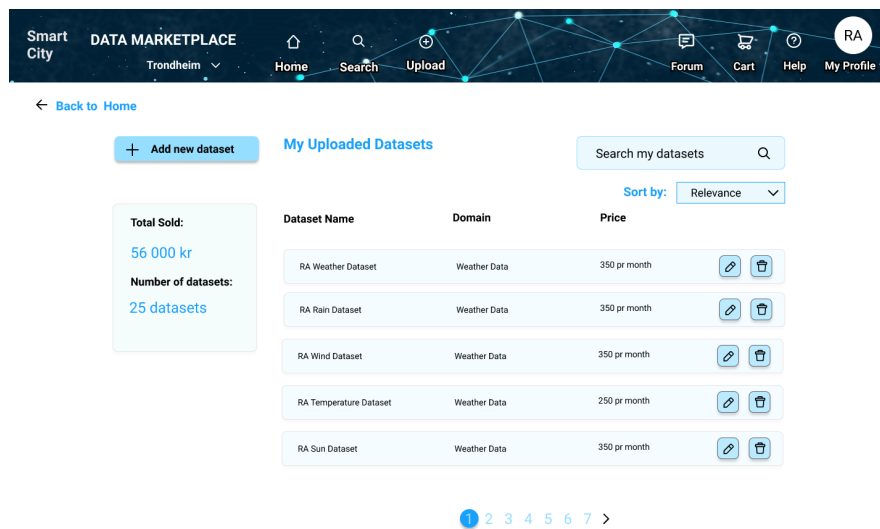
Figure 7.19: Screenshot of Upload Dataset Page, Fourth Iteration, Figma design prototype.

Register New Dataset Page

Figure 7.20 shows the screenshot of the updated register new dataset page. In this iteration the pages for registering information about the metadata, map, visualizations and use cases was designed.
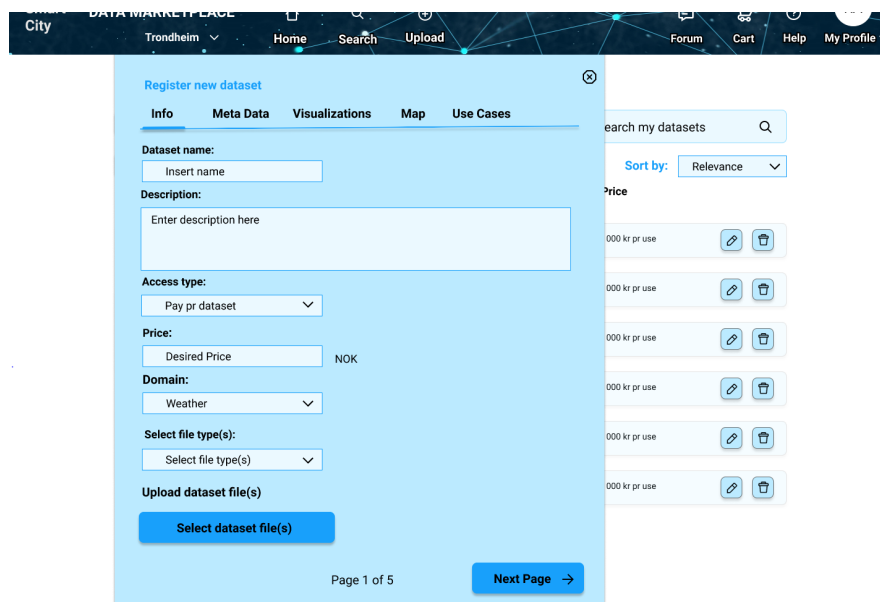
Figure 7.20: Screenshot of Register New Dataset Page, Fourth Iteration, Figma design prototype.

Forum Page

Figure 7.21 shows the screenshot of the new forum page. The design was inspired by popular forums, and has tabs for popular posts, newest post etc. The forum is a place for the users to discuss topics related to datasets and get tips and suggestions from the community.
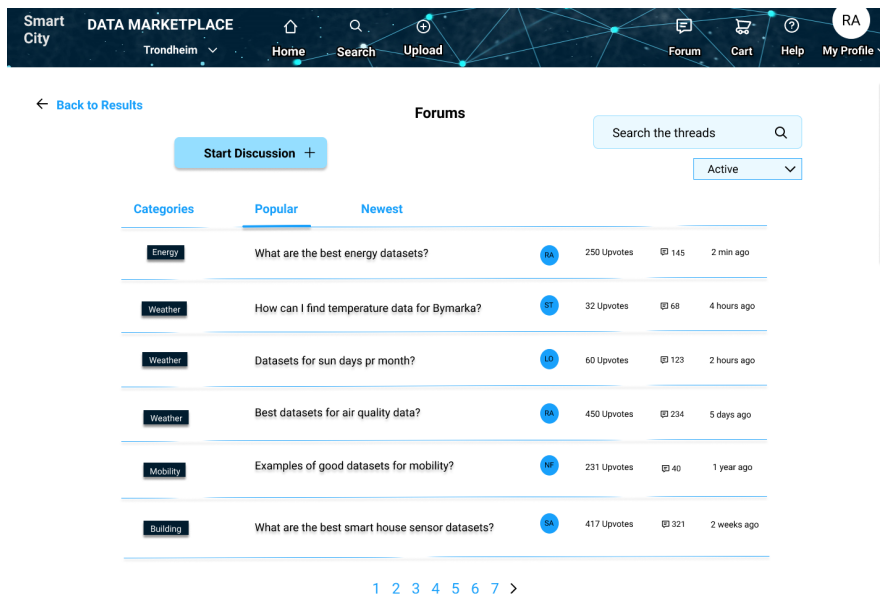
Figure 7.21: Screenshot of Forum Page, Fourth Iteration, Figma design prototype.

Menu Bar

The design of the menu bar was changed by simplifying the text from "search data" and "upload data" to just "search" and "upload". The menu also got a picture background that fits the blue aesthetics of the platfrom and simulates the data nodes of a dataset. The colors of the text was changed to white to stand out from the background and the symbols were made bigger to better show the calls to actions and topics. The link to the Figma prototype can be found in the user guide in Appendix A.

7.4 Evaluation

The results from the evaluations of the fourth iteration can be found in the Final Evaluations and Results chapter 8.

7.4.1 Retrospect of the Fourth Iteration

In retrospect the researcher see that the change from "search data" and "upload data" to just "search" and "upload" would be understandable for experts in the

data marketplace, but less understandable for new users. The text could be kept as "search data" and "upload data".

For further iterations of the prototype in future work it would be interesting to also test the prototype on less technical people. This is important since the platform should also be understandable and easy to use for less technical customers.

7.5   Summary

This chapter has described the updated requirements, customer journeys and EA model, the prototype design, the expert evaluations of the prototype and the evaluations of the EA modeling and customer journeys approaches of the fourth iteration. The final evaluation and the results are described in Chapter 8.

Chapter 8

Final Evaluation and Results

This chapter includes a summary of the demographics and prior knowledge level of relevant topics for the participants of the user testing and expert evaluations of all the four iterations. It also describes the participants' descriptions and the proposed definition of a data marketplace and a smart city data marketplace. Further the section includes the results from the final evaluation of the fourth iteration, the expert evaluations results, the total list of requirements for the data marketplace, the results from the evaluation of EA modeling and customer journeys approaches and the proposed EA model of the smart city data marketplace.

8.1   Participants

This section shows the demographics of the participants in the user testing and expert evaluations and their prior knowledge level on relevant topics.

8.1.1   Demographics of Participants

Table 8.1 shows the demographics of the participants of the user testing and expert evaluation sessions.

The participants were recruited from the supervisors' and the researcher's network. Several of the experts were also partners of the +CityxChange project. The selection of participants was done based on the need for experts of smart contracts and crypto currencies, system development and EA modeling. The three user testers were recruited from the researcher's own network.

The participants represented both the education and research sector, the bank and economics sector, the energy sector, the biology sector, the software development sector and the crypto currencies sector. These are very relevant sectors for the smart city data marketplace.

Expert1 evaluated him self as 2 in prior knowledge level of all the topics, but he was highly knowledgeable in the area of using data in cities and neighbourhoods. His PhD is related to the Research Centre on Zero Emission Neighbourhoods in

Table 8.1: Demographics of Participants

ID	Age Group	Role	Company
User Tester1	20-29	Marine Biologist	Åkerblå
User Tester2	20-29	Software Developer	TietoEvry
User Tester3	20-29	Cyber Security Student	NTNU
Expert1	20-29	PhD Candidate Stipendiat	NTNU
Expert2	40-49	System Architect	FourC
Expert3	40-49	Senior Researcher	NTNU
Expert4	40-49	Head of Technology Infrastructure	IOTA
Expert5	30-39	PhD Candidate Stipendiat	NTNU
Expert6	30-39	Senior Data Scientist	DNB
Expert7	30-39	Software Engineer	DNB
Expert8	30-39	Lead Machine Learning Engineer	TrønderEnergy

Smart Cities - FME ZEN. This makes his expert knowledge relevant for the master's thesis. Expert4 is an expert on crypto currencies and expert5 is an expert on smart contracts and his PhD focuses on smart contracts. Expert7 worked with the internal data marketplace in DNB. Expert8 had been a sensor for several master thesis related to data marketplaces.

The distribution of the participant's age groups were 36,4% of the 20-29 years old age group, 36,4% for the 30-39 year old age group and 27,3% for the 40-49 years old age group.

Figure 8.1 shows a pie chart of the distribution of gender of the participants. It shows that there were 72,7 % male and 27,3 % female participants. It would be interesting and beneficial to have a more equal representation of gender in future evaluations of the prototype and further research on the smart city data marketplace topic.
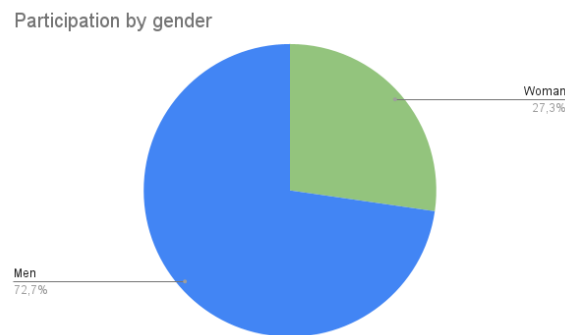
Figure 8.1: The diagram shows the participation by gender.

8.1.2 Prior Knowledge Level

Table 8.2 shows the participants' answers to rating their prior knowledge level related to the topics data marketplaces, user testing, design prototyping and system development. The following 5-points Likert scale was used for evaluating the prior knowledge level of the participants: 1= Very low level, 2= low level, 3= neutral, 4= high level, 5= very high level.

Table 8.2: Prior Knowledge Level of Participants

ID	Data Marketplace	User Testing	Design Prototyping	System Development
UserTester1	1	1	1	1
UserTester2	1	3	3	5
UserTester3	1	3	2	4
Expert1	2	2	2	2
Expert2	5	3	5	5
Expert3	3	4	4	4
Expert4	4	3	3	4
Expert5	3	5	3	4
Expert6	4	5	5	5
Expert7	3	3	4	5
Expert8	4	4	4	5

All the experts answered that they work with data and or open data. Many of the experts and user testers had never heard about the specific term data marketplace before. It is interesting that even though they work with data they had not heard about the term data marketplace before.

An expert said that "I don't have any correlations that pass my mind when I hear data marketplace. I can understand the words, but I can't recall any place that I can go now and say I want to buy some data, let's go to the data marketplace". On the other hand, many of the experts had much experience with using open data portals with free public data.

8.2 Proposed Definition of a Data Marketplace

In the start of each user testing and expert evaluation session the participants were asked to describe a data marketplace and smart city data marketplace in their own words. Tables 8.3 and 8.4 show the participants' descriptions of a data marketplace and a smart city data marketplace.

Table 8.3: Descriptions of a Data Marketplace

ID	Description of a data marketplace
UserTester1	"I think a data marketplace is probably a marketplace for selling computers"
UserTester2	"I think it is a platform such as FINN.no for selling and buying data"
UserTester3	"A place where you can buy and sell data"
Expert1	"I imagine that it is a place where you can trade data simply, that it is a kind of FINN.no or something like that for data. That you can request and post available data etc."
Expert2	"A portal where different kind of data within a specific domain, are made available for someone to pick and use or buy, rent"
Expert3	"I don't think there is a clear definition, but a data marketplace would be a business to business marketplace of specific data and functionally to exchange it" "
Expert4	"A website where I can go and search for data based on different properties, location, types of data and I can receive feeds on this data from many different places, maybe from a number of cities. I might have to pay some fee to access this data, but i might also be able to use some of the sources for free"
Expert5	"A platform that shares and sells large versions of data or big data.
Expert6	"A common area where data can be offered as a product a bit like a data product and it can be different licenses and different ways to share, can be based on membership etc, and there are many business models on the marketplace and it can also be completely open data where everyone contributes to it, a bit like the type of charity data, and it can be linked to it can be public who do it and also, consortia, it comes in many forms I think"
Expert7	"A place where data is made available, and that you can retrieve either by doing your own operations on it before retrieving it, or taking out predefined tables."
Expert8	"A place where data providers and those who want to obtain data meet, a bit like the app store, if you have some data then you can post it there and get paid for it. All typical features like search, data quality check, setup that makes it easier to buy and sell data, an app store for data"

The descriptions from UserTester1, UserTester2, UserTester3, Expert1, Epert6, Expert7 and Expert8 were given in Norwegian, and therefore they needed to be translated into English. The table shows the translated versions. It is interesting that UserTester1 thought that a data marketplace was a place for selling computers. It is a natural thought, since the name data can be used for computers in Norwegian.

Table 8.4: Descriptions of a Smart City Data Marketplace

ID	Description of a smart city data marketplace
UserTester1	"I think a data marketplace is probably a marketplace for selling computers"
UserTester2	"A collection page where I can find data from all cities and data generators"
UserTester3	"A place to buy and sell data"
Expert1	"For a smart city data marketplace it would have been maybe, then it's about energy I would say then to a large extent I envision at least, and things related to it of course and that kind of access to data for logistics and bus and so on, and a bit like that municipal platform I see for myself maybe, like where you share data then."
Expert2	"Maybe there is more specific kind of data, so there is data from the smart city, some data related to mobility, something related to energy and this kind of thing. It is the same as a data marketplace but more specific."
Expert3	"A place to buy and sell data"
Expert4	"I think in the end smart city or data marketplace is just a label of the type of data. I know there may be different data, but if describing from a infrastructure point of view it is not much difference in a data marketplace and a smart city data marketplace. "
Expert5	"Not answered"
Expert6	"I think smart city is all that has to do with IoT, I would think energy use, maybe real life traffic data, everything from the consumption of natural resources, and things that can be measured on IoT, everything from heating to connectivity such as internet use."
Expert7	"It would be the same, I don't think it is so very different from what they do in the bank, transaction data, sensor data and things like that."
Expert8	"It must be a data marketplace with real time data, not so much static data, preferably sensor data"

8.2.1   Proposed Definition of a Data Marketplace

A new definition of a data marketplace and a smart city data marketplace were proposed based on findings from literature review, background study of existing data marketplaces and the participants' descriptions in tables 8.3 and 8.4. The new proposed definition of a data marketplace is as follows:

Def: A data marketplace is a digital platform for easy selling, buying and sharing of data.

The findings from this thesis consider a smart city data marketplace to be very similar to a general data marketplaces, besides the fact that the data comes from the smart city. Examples of the data sources are IoT sensors, citizens and businesses in the smart city. The new proposed definition of a smart city data marketplace is as follows:

Def: A smart city data marketplace is a digital platform for easy selling, buying and sharing of data that mainly come from smart city data sources such as internet of things (IoT) sensors, citizen and business data from the smart city.

8.3   Results from the Final Evaluations

This section covers the steps of the "Evaluation" phase of the fourth and final iteration. It includes the expert evaluations of the prototype and the evaluations of the EA modeling and customer journeys approaches.

8.3.1   Fourth Iteration Evaluation: Expert Evaluations

This subsection describes the expert evaluations of the fourth iteration. Figure 8.2 shows the expert evaluations step in the iteration.
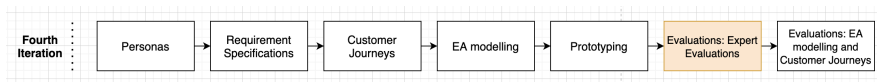
Figure 8.2: Expert Evaluations, fourth iteration.

The subsections covers the profiles of the three participants, the user testing, feedback with suggested improvements and the results from the TAM evaluations.

Figure 8.3 shows the parts of the expert evaluations. It consisted of demographics and prior knowledge of the experts, a user testing session, feedback with suggestions for improvements and TAM evaluations of the data marketplace.

The expert evaluations of the fourth iteration consisted of three sessions with one participant each, and were conducted for approximately 1-1,5 hours each session. The expert evaluations were conducted in the same way as in the third iteration and the Expert evaluations method is thoroughly described the Methods Chapter 3.
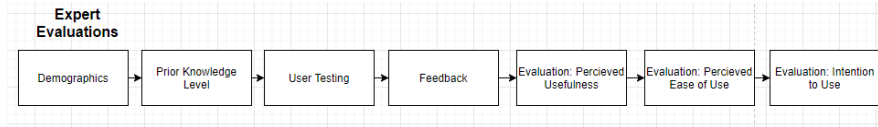
Figure 8.3: Illustration of the parts of the expert evaluations in the fourth iteration.

Expert Profiles

The first part of the expert evaluations consisted of gathering demographics and prior knowledge level of central topics of the participants. Table 8.5 shows the demographics of the participants. Expert6 had worked with the internal data marketplace for DNB and Expert8 had been an external sensor for several master's thesis related to data marketplaces.

Table 8.5: Fourth Iteration Demographics of Participants

ID	Age Group	Role	Company
Expert6	30-39	Senior Data Scientist	DNB
Expert7	30-39	Software Engineer	DNB
Expert8	30-39	Lead Machine Learning Engineer	TrønderEnergy

Table 8.6 shows the experts' answers to rating their prior knowledge level related to the topics data marketplaces, user testing, design prototyping and system development. The following 5-points Likert scale was used for evaluating the prior knowledge level of the participants: 1= Very low level, 2= low level, 3= neutral, 4= high level, 5= very high level.

Table 8.6: Fourth Iteration Prior Knowledge Level of Participants

ID	Data Marketplace	User Testing	Design Prototyping	System Development
Expert6	4	5	5	5
Expert7	3	3	4	5
Expert8	4	4	4	5

User Testing

The next part consisted of user testing of the data marketplace prototype. Table 8.7 shows the user stories for the user testing in the fourth iteration. The experts had no problems to test the user stories. The user testing showed that the experts would like to have more metadata on the dataset information page to make it easier to evaluate if the data fits their own requirements.

Table 8.7: Fourth Iteration User Stories

ID	User Story	Comment
UserStory1	As a user you should find data realted to weather and select the TW Temperature Dataset.	No problems
UserStory2	As a user you should find the information about metadata, use cases and map for the TW Temperature Dataset.	Suggested Improvements
UserStory3	As a user you should add the TW Temperature Dataset to cart and checkout.	No problems
UserStory4	As a user you should filter your search on JSON file type.	No problems
UserStory5	As a user you should request a new dataset.	No problems
UserStory6	As a user you should start a new discussion in the forums.	No problems
UserStory7	As a user you should upload a new dataset.	Suggested Improvements
UserStory8	As a user you should go to home page and find the success stories and new datasets.	No problems

All the experts were able to find the metadata, map and use cases info, but they had some suggestions for more information they would like to have in the different sections to make it easier to assess if the dataset is a good fit or not for their project. All the experts were able to find the request new dataset button, and they said it was a good option for the platform. One expert stated that it should be called something else like "place an ad".

Two of the experts were able to find the upload dataset page without problems. One expert tried to find the upload dataset option under My profile, and suggested that it might be better to call it sell instead of upload to make the navigation clearer. One of the experts would like to have examples of how to fill in the fields in the register new dataset pages. All the expert were able to find the home page and find the success stories, but one expert though it was difficult to know that the bullet points was not clickable, and wanted an "About the page" section on the Home page.

Table 8.8 shows the expert suggestions for improvements for the fourth iteration.

Generally the experts liked the design of the third iteration and said it was modern and intuitive and very easy to use. All the experts would choose traditional payment methods over smart contracts and crypto currencies, but said it was nice to have both options available, especially for the future. Two of them was sceptical to crypto currencies in general.

Suggestion S1, S2 and S3 in table 8.8 was evaluated as "Nice to have" for

future work. Suggestions S4, S5, S6, S7, S11, S12 are evaluated as "must have" for a good quality and usefulness of the platform if it should be a fully implemented platform, but nice to have if it is an MVP.

Table 8.8: Fourth Iteration Expert Suggestions

ID	Suggestion	Review	Evaluated as
S1	Add examples of ways to fill out the different sections in the register new dataset pages	Nice to have	Future Work
S2	Add more technical filters related to API	Nice to have	Future Work
S3	Add more relevant metadata that can help show the value of the dataset i.e last updated, number of null values and number of data points	Must Have	
S4	Have a list view of the metadata	Nice to have	Future Work
S5	Rather call it pay pr. package and with an info box on what a package means	Nice to have	Future Work
S6	Call the request dataset something else, for instance place an ad	Nice to have	Future Work
S7	Use smart contracts also for verifying the quality of the data	Nice to have	Future Work
S8	Add fields for registering an API for dynamic data streams in the register dataset page	Must have	Future Work
S9	Add a section about policies, GDPR, and not too restrictive copyright rules	Must have	Future Work
S10	Add options for crowd sourcing of data/ generation of datasets based on answers from the citizens, and reward the participants	Nice to have	Future Work
S11	Add a standard swagger api that can be used by the data sellers (get, post)	Nice to have	Future work
S12	Add a page with overview of requested datasets where the sellers can see what data the customer's need, similar as the design of FINN.no	Must have	Future Work

Evaluations (TAM)

The next part consisted of evaluations inspired by the Technology Acceptance Model (TAM) that focused on the three aspects perceived usefulness, perceived ease of use and intention to use the data marketplace[68]. Table 8.9 shows the experts' answers to rating the perceived usefulness of the prototype, the perceived ease of use, the intention to use the data marketplace to buy data professionally,

buy data privately, sell data professionally, sell data privately and the intention to recommend the data marketplace to others. The following 5-points Likert scale was used for evaluating the usefulness and ease of use: 1= Very low level, 2= low level, 3= neutral, 4= high level, 5= very high level. The intention to use the data marketplace for buying and selling data, and recommending it to others used the following Likert scale: 1= Highly unlikely, 2= not likely, 3= neutral, 4= likely, 5= very likely.

Table 8.9: Fourth Iteration TAM Evaluations

ID	Usefulness	Ease of Use	Buy Professionally	Buy Private	Sell Professionally	Sell Private	Recommend to others
Expert6	4	5	4	3	2	2	5
Expert7	4	5	5	5	4	5	4
Expert8	4	5	4	2	3	3	4

Perceived Usefulness

The average rating for usefulness of the prototype was 4, which indicates that the experts thought the data marketplace would provide value.

Expert6 stated that it was most important for the usefulness that there are good quality data on the platform, and the answer depends on this. If it was good and much quality data on the platform it would be a 4 or 5 on usefulness of the prototype. Expert7 stated that it was a 4 on usefulness of the prototype and that the most useful aspect was the function to search for datasets.

Perceived Ease of use

All the experts stated that it was a 5 on ease of use of the prototype, which indicates that the prototype is very easy to use. Expert6 said it was very easy to use and navigate. Expert7 said it was very intuitive and modern design and easy to use, and similar to normal shopping experiences, which is good. Expert8 said the prototype was easy to use and the design was good for a catalog over dataset from the smart cities like Trondheim.

Intention to Buy Data

The average rating for buying data professionally was 4.33 which indicates that it was likely that the experts would use the data marketplace to buy data for their work. On the other hand, the average rating for buying data privately was 3.33, which shows that it currently is less interest for buying data for private use.

Intention to Sell Data

The average ratings for selling data professionally 3, and privately were 3.33, which indicates that there experts were neutral to selling data in the data marketplace.

Recommend to others

All the experts stated that they would recommend the data marketplace to others. The average rating was 4.33 which indicates a high willingness to recom-

mend it to others.

Need for a data marketplace for the Smart city Trondheim

All the experts stated that they saw a need for the data marketplace for Trondheim. Expert7 stated "There is absolutely a need for a data marketplace for Trondheim, since there are many use cases and companies that need data ".

Scenarios where the Smart City Data Marketplace would be useful

The experts listed many scenarios where the smart city data marketplace would be useful. This include the following:

- It can be useful within optimization, sustainability reporting of companies and financial actors
- Help measure the effects of efforts of emission reduction in terms of the Paris agreement.
- Help see consumption patterns, management of smart houses and smart entities
- Help waste management, with checking if trash cans are full or not.
- Get indication of services to offer for the city, provide insight to startups and create innovation.

8.3.2 Evaluation of the EA modeling and Customer Journeys Approaches

This section describes the evaluation of the EA modeling and customer journeys approaches in the fourth iteration. Figure 8.4 shows the evaluation of the EA modeling and customer journeys approaches step in the iteration.

Figure 8.4: Evaluation of EA modeling, fourth iteration.

Expert7 also participated in an evaluation of the approaches EA modeling and customer journeys. He had prior experience with EA modeling and customer journeys. Table 8.10 shows the evaluation of the EA modeling and customer journeys approaches that were used in this research project. The following 5-points Likert scale was used for evaluating how easy it is to understand the approaches and the value of using EA modeling and customer journeys for planning and design of a data marketplace: 1= Very low level, 2= low level, 3= neutral, 4= high level, 5= very high level.

Table 8.10: Fourth Iteration Evaluation of EA Modeling and Customer Journeys Approaches

ID	Usefulness of EA modeling	Easy to understand EA modeling	Usefulness of customer journeys	Easy to understand Customer Journeys	Usefulness of combining both approaches
Expert7	4	5	5	4	5

Expert 7 evaluated the usefulness of the customer journeys approach and of combing the two approaches to plan and design the data marketplace as very high level of usefulness. He stated that "One should use both, some form of EA modeling and some form of customer journeys, since it looks at different aspects". He evaluated the usefulness of the EA modeling as high level and stated that "I would have used something like EA modeling myself if I should make the platform". He rated all the approaches as very easy to use.

8.4 Expert Evaluations Results

This section describes and compares the results from the expert evaluations in the third and the fourth iteration.

Figure 8.5 shows a radar diagram with the average answers from expert evaluations in the third and the fourth iteration.
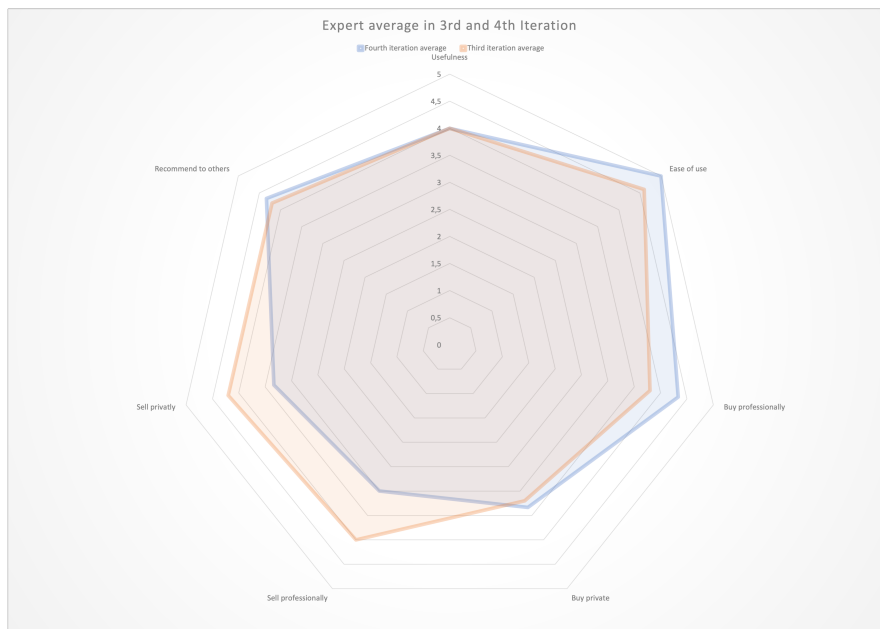
Figure 8.5: Radar diagram of the average answers from expert evaluations in the third and the fourth iteration

Perceived Usefulness

Figure 8.5 shows that the average rating of perceived usefulness was 4 (high level) in both the third and the fourth iteration. This shows that the experts were in agreement for the level of usefulness of the prospoed smart city data marketplace prototype.

Perceived Ease of Use

The average number of ease of use of the prototype was 4.6 in the third iteration and 5 in the fourth iteration. This indicates that the ease of use and user experience was improved trough the iterations. Nevertheless, all the experts stated that the prototype was very intuitive, easy to use and had a good user experience in both the iterations.

Intention to Buy Data

The average rating for using the platform for buying data professionally was 3.8 in the third iteration and 4.33 in the fourth iteration. These ratings were quite similar, but the differences might also be caused by the number of participants in the iterations and their work areas.

The rating of buying data privately was 3.2 in the third iteration and 3.3 in the fourth, which indicates that the experts were more inclined to buy data professionally, compared to privately, which is natural.

Intention to Sell Data

The rating for selling data professionally was 4 for the third iteration, and 3 for the fourth iteration. For selling data privately, the rating was 4.2 for the third iteration and 3.3 for the fourth iteration. These ratings show that the likelihood for selling data both professionally and privately, was more likely for the experts in the third iteration compared to the fourth iteration.

Recommendations to others

All the experts in both the third and fourth iteration answered that they would recommend the prototype to others.

The Need for a Data Marketplace in Trondheim All the participants answered that there is a need for a data marketplace for Trondheim smart city and other smart cities. The initial three user testing sessions also showed that the participants saw a need for a data marketplace in Trondheim and other smart cities.

Smart Contracts and Crypto Currencies

On the question of which payment method they would prefer over traditional and crypto currencies, all the experts preferred the traditional payment methods. On the other hand, the majority of the experts stated that they would like to have both options in the platform. Several experts stated that they were sceptical to using crypto currencies in general.

8.4.1 Total List of Requirements

Table 8.12 shows the total list of requirements gathered from the findings in the user testing, expert evaluations and the findings from literature review trough the four iterations of the research project.

Table 8.11: Total List of Functional Requirements

ID	Functional Requirement	Status
FR1	Must have a search data page, information dataset pages (with information about metadata, visualizations, map, use cases), an upload data page, check out page, a registering a new dataset page, a user profile page, a cart page	Designed
FR2	Must have functionality for filtering the search	Designed
FR3	Must be scalable for many users and datasets	Designed
FR4	Must be possible to find both open data and pay per use or hour datasets	Designed
FR5	Must have a rating system	Designed
FR6	Must have well strucutred and relevant metadata	Partly designed
FR7	Should be a semi-decentralized marketplace	Designed
FR8	Should have options for both smart contracts and traditional payment methods	Designed
FR9	Should have possibility to organize the view on grid and list view, and filter the results by last updated, price, relevance for the results	Designed
FR10	Should have a home page (with statistics, success stories, how to use the platform etc) and a forum page	Designed
FR11	Should have functionality to request a new dataset and links to other data portals	Designed
FR12	May have alternatives to use Smart city data marketplace tokens	Future work
FR13	May have incentives for using the data marketplace (i.e. get Smart city data marketplace SCDM tokens, buy one, get one free)	Future work

8.5 Results from Evaluation of EA Modeling and Customer Journeys Approaches

This section includes the results from the evaluation of the EA modeling and customer journeys approaches. The approaches were evaluated to get an external opinion on the value and usefulness of the chosen approaches for planning and designing a system such as a data marketplace. The evaluations helped to answer research question RQ3 on how EA modeling and customer journeys can support the planning and design of a data marketplace.

Five experts participated in the evaluations of the approach, Expert2, Expert3, Expert4, Expert5, Expert7. All of these experts had prior knowledge of EA modeling, and five of the experts had also participated in the +CityxChange project and

Table 8.12: Total List of Non-Functional Requirements

ID	Non-Functional Requirement	Status
NFR1	Must be easy to understand	Designed
NFR2	Must require few second to understand how to use the system	Designed
NFR3	Must require few clicks for using the main functionalities (sell or buy data)	Designed
NFR4	Must have good user experience	Designed
NFR5	Should use similar design as existing electronic marketplaces to make it familiar and easy to use	Designed
NFR6	Should use colors and fonts that is easy to read	Designed
NFR7	Should have information icons with explanations of difficult terms	Designed
NFR8	Should have return buttons on every page for easy navigation	Designed

was somewhat familiar with the EA framework used for this research project.

The EA modeling approach was also evaluated by three user tester participants with no prior knowledge of EA modeling in the first and second system design iterations. Table 8.13 shows the evaluation of the EA modeling and customer journeys approaches that were used in this research project.

The following 5-points Likert scale was used for evaluating the value of using and how easy EA modeling and customer journeys are to use: 1= Very low level, 2= low level, 3= neutral, 4= high level, 5= very high level.

Table 8.13: Total Evaluations of EA Modeling and Customer Journeys Approaches

ID	Usefulness of EA modeling	Easy to understand EA modeling	Usefulness of customer journeys	Easy to understand Customer Journeys	Usefulness of combining both approaches
Expert2	5	5	5	5	5
Expert3	4	5	4	4	4
Expert4	2	2	5	5	3
Expert5	5	5	5	5	5
Expert7	4	5	5	4	5

Figure 8.6 shows a radar diagram with the answers from evaluation of the EA modeling and customer journeys approaches in the third and fourth iterations.
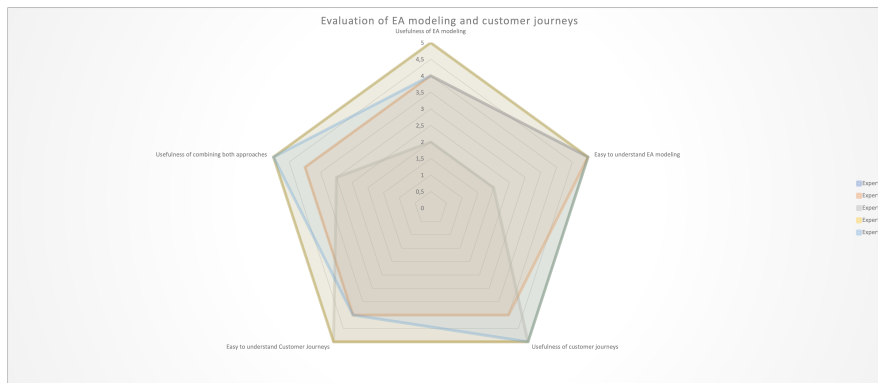
Figure 8.6: Radar diagram of the evaluations of the EA modeling and customer journeys approaches in the third and the fourth iteration

The ratings from the experts showed that the majority evaluated customer journeys to be very important and very high level of usefulness for planning and designing a data marketplace. It also showed that EA modeling was evaluated to be a high level of usefulness with an average rating of 4.

The majority of the participants were in agreement in their answers towards EA modeling, but one of the participants rated the approach as both low level of usefulness and easy to understand. This shows that there can be individual preferences and opinions that do not see the value of the EA approach.

Table 8.13 shows that the average rating for usefulness of combining both EA modeling and customer journeys to plan and design the data marketplace was 3.66, which is close to a high level of usefulness. The combination of the two disciplines EA and Service design is a novel approach. Therefore it is extra interesting to explore how external experts of data evaluated the usefulness of the approaches.

8.6 Proposed EA Model of the Smart City Data Marketplace

This section includes the proposed EA model of the smart city data marketplace. It was updated based on the findings and changes in the four iterations of the project. Figure 8.7 shows the proposed EA model of the smart city data marketplace. The changes to the initial EA model in the first iteration are related to the Context layer, Services layer, Data Space layer and the Technologies layer. The changes to the context layer include some new goals such as improving descoverability, ease to check quality of data, easy and secure data trading and helping to reach UN Sustainable Development Goals. The changes to the services layer, are new services for requesting data and use the forum discussions, inclusion of the find free open data service, and having options for paying with both traditional payment methods and smart contracts. The data space layer has info for using Dublin Core

as the metadata standard and includes the changed pricing models for the data marketplace, based on trends in the data trading landscape and feedback from experts. The changes to the technologies layer are the new semi decentralized network type of the data marketplace. In general there were most changes to the services layer of the model.
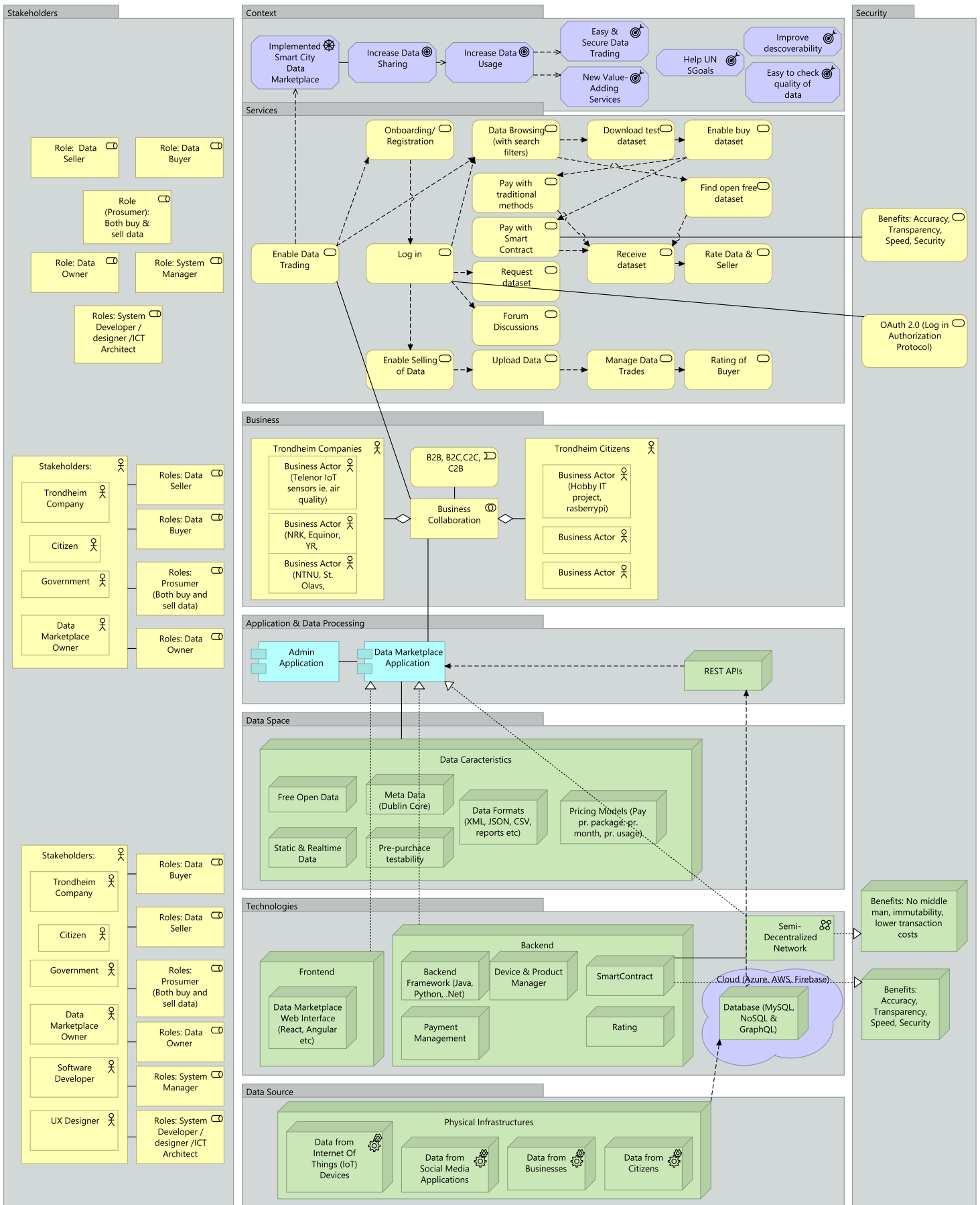
Figure 8.7: Proposed EA model of the Smart City Data Marketplace

8.7   Summary

This chapter has shown a summary of the demographics and prior knowledge level of all the participants of the user testing and expert evaluation sessions in the four iterations, as well as the descriptions and proposed definition of a data marketplace, and the results from the final expert evaluations and total expert evaluations results. It also showed the total list of requirements, the results from the evaluation of EA modeling and customer journeys approaches and the proposed EA model of the smart city data marketplace.

Chapter 9

Discussion

This chapter shows the discussions of the findings from the study, including novelty of prototype, how the findings provide answers to research questions, discussions related to research questions, data marketplace and UN sustainability goals and the lessons learned.

9.1   Novelty of the Proposed Prototype

This section describes the novelty of the proposed prototype and how it is different to open data portals.

The aspects that make the proposed data marketplace prototype different from existing data marketplaces are that the platform has options for both smart contracts and tradition payment methods, the new discussion forums and the new "request dataset" functionality. The "request a dataset" functionality was not found in any of the existing data marketplaces in the background study. This feature was highly requested by four of five participants in the third iteration, which indicated a need for such functionality for the smart city data marketplace.

Another difference to many existing data marketplace is that the prototype provides both free open data and data for sale. The data marketplace also have features for improving the discoverability of datasets, such as the links to related open data portals, the discussion forums and the "request dataset" functionality for findings data that are not already in the data marketplace.

Other novel aspects of the proposed prototype are the focus on customer needs, user experience, accessibility and ease of use for both technical and less technical users. The prototype design have several features that help make the platform more accessible and easy to use for the customers. These features are for instance the "home" page with intro to what you can do on the platform, the "help" page and the "forum" page were the customers can ask questions, receive advice and discuss datasets etc. Technical terms also have an info icon with explanations of the terms to help new or less technical users. The example of suggested use cases on the dataset information page and the success stories the "home" page are also included to help and inspire the customers for how to use the datasets.

The master's thesis has shown that there is a need for high quality data and different possibilities to check the quality and relevance of the data before buying. The proposed prototype has functionalities to help evaluate the quality of the data, such as rating of the datasets and the data seller, possibility to download a test dataset before buying it, well structured, relevant and descriptive metadata with the Dublin Core standard and suggested use cases of the datasets. The prototype also have contact information to the data seller, seller profiles with more info about the seller and verification badges for verified sellers.

The design of the proposed prototype was influenced by the background study of the existing data marketplaces and open data portals. The aim was to have a design that was familiar and easy to use for the customers. Therefore the prototype use similar layout and design choices as popular existing electronic marketplaces such as Finn.no, AirBnb and Ebay. The background study showed that the open data portals had many design choices that would be beneficial for the smart city data marketplace, such as the buttons for categories. The prototype can be seen as a merge between open data portals and data marketplaces with the focus on smart city data.

Differences of the Data Marketplace and Open Data Portals

As mentioned earlier, the main difference between the smart city data marketplace and open data portals is that the data marketplace have options for selling and buying data in addition to uploading and finding free open data. The background study of the existing platforms showed that the data marketplaces often had better user experience compared to the open data portals. This may be since the data marketplaces are commercial platforms that needs to attract enough buyers and sellers to be profitable, instead of a open data portal that is funded by the government. Other differences between the two Trondheim open data portals and the new proposed data marketplace prototype is that the new smart city data marketplace has more functionalities like discussion forums, request a new dataset and smart contracts.

9.2 Answers to Research Questions

This section discusses how the thesis helped provide answers to the research questions RQ1, RQ2, RQ3 and the related sub research questions.

9.2.1 Research Question 1

RQ1: What is a data marketplace and what are the main challenges and trends in the data marketplace landscape?

RQ1 and "what is a data marketplace" can be answered by the new proposed definition that can be found in the Final Evaluations and Results chapter 8. The definition was based on both the literature review, background study of existing data marketplaces and the descriptions of a data marketplace by the user testers and expert evaluations. The semi-structured interviews and evaluations of the

proposed data marketplace prototype also provided many interesting insights and discussions of what is the challenges and trends in data marketplaces. The main finding is that quality of data and relevant and well strucutred meta data are one of the most important aspects of a data marketplace. It also showed the trend of decentralized data marketplaces and the use of both traditional payment methods and smart contracts are nice to include. Still most of the experts would not use smart contracts today. The smart contracts can be seen as a functionality of the future that would be very interesting if more people started using crypto currencies.

This research question was important to be able to thoroughly investigate the domain, identify trends, challenges, possible solutions and define relevant requirements for the new prototype. The approaches such as literature review and personas were helpful to specify requirements.

RQ1.1: How can we best define the concept of a data marketplace?

As mentioned in the literature review chapter there are no clear definition of a data marketplace. The thesis helps provide answers to RQ1.1 by proposing a new definition of a data marketplace in the Final Evaluations and Results chapter 8, subsection 8.2.1. The proposed definition is based on findings from literature review and background study of existing data marketplaces. It was also inspired by the user testers' and experts' descriptions of a data marketplace. An interesting finding is that several experts did not know the term data marketplace, even though they work with data each day. This indicates that "data marketplace" is not yet a widely known term and is still somewhat in its infancy. This might also explain why there are no clear definitions of the term in academic papers. On the other hand, the experts had much experiences and knowledge of using open data portals which shows that there is a high need for data.

RQ1.2: What are the main trends in the data trading landscape?

The literature review and background study of existing data marketplaces in chapter 2, show that there is a trend of transitioning from centralized towards decentralized data marketplaces. As mentioned in chapter 2, the trends include using smart contracts, crypto currencies and tokens for payments in the data marketplaces. On the other hand, the expert evaluations showed that there are still scepticism towards blockchain and crypto currencies among experts who work with data.

RQ1.3: What are the major challenges related to data marketplaces?

The thesis provides answers to RQ1.3 by exploring and showing the main challenges for data marketplaces in the literature review chapter 2. As mentioned earlier, the main challenges involve how to show, evaluate and ensure quality of the data, how to ensure trust in the buyers and sellers, how to ensure secure transactions and how to handle data ownership and privacy, GDPR and legal issues in the data marketplaces.

RQ1.4: What are the limitations of the existing smart city data marketplaces?

The thesis helps answer RQ1.4 by showing findings from the literature review

and background study of data marketplaces and smart city data marketplaces. As mentioned in chapter 2, there are several papers on specific implementations of data marketplaces for smart cities such as the i3 and n [14]. A limitations of the studied data marketplaces for smart cities is that they does not focus much on user experience. This is natural since most of them are early research project prototypes and has more focus on how to implement the decentralized features rather than making it easy to use for the customers. Additionally, the use of nearly fully decentralized platforms with both decentralized payment method and storage, and only having options for smart contracts makes it more difficult for citizens to use the data marketplace. Therefore this thesis focused on the user needs, user experience and ease of use for the smart city data marketplace prototype. The proposed data marketplace uses a partly decentralized network type and has options for both smart contracts and traditional payment methods. This was done to make the platform accessible for both technical and less technical users in the smart city.

9.2.2 Research Question 2

RQ2: Is there a need for a data marketplace for a smart city like Trondheim and what is needed in such a platform?

RQ2 is answered based on all the interesting suggestions, discussions and evaluations from the user testings and the expert evaluations. Based on the expert evaluations it is clear that there is a need for a data marketplace for the smart city Trondheim and smart cities in general.

The main findings are that it is important to be able to see and evaluate the quality of data in an easy manner and have the possibility to request data. The expert evaluations showed that all the functionalities in the proposed prototype are important and useful for such a platform. The findings from the "intention to use"-part of the expert evaluations show that many of the experts would use the data marketplace to buy data professionally, but few would buy data for private use. The same goes for selling data. Most of the experts did not have datasets to sell, but they stated that they would be happy to sell if they had any.

RQ2.1:How to design a data marketplace that supports the needs of a smart city and what is the important functional and non-functional requirements for such a platform?

The user testing and expert evaluation sessions of the data marketplace prototype provided crucial feedback on what the participants liked, missed and needed in the smart city data marketplace. The suggestions for improvements helped refine and focus the requirements for the data marketplace to fit the needs of the users. The total list of requirements for the smart city data marketplace can be found in the Final Evaluations and Results chapter 8. It is one of the contributions of the thesis.

RQ2.2: How can we best ensure quality of the data and trust in the data marketplace?

As mentioned in chapter 2, the need for good metadata is very important to help the buyer evaluate if the data fits their own requirements. The importance of metadata is stated in the paper by Lawrenz et al. and it is also one of the main findings from the expert evaluations [12]. The experts stated that it is very important with good and relevant metadata, since it is one of the few ways that you can find out if the data is a good fit for your tasks. This finding supports and extends the paper by Lawrenz et al. [12]. An other aspects that is important for ensuring quality in the data marketplace is the option to test some of the dataset before buying it. The experts stated that the pre-purchase testability was very important and positive for the platform. Other aspects that can be positive for ensuring both trust in the platform and quality of the data are the ratings of the datasets, preview of the dataset and verification of the seller. The smart contracts and copyrights agreements can also help ensure trust in the data trade between buyer and seller.

RQ2.3: How to make both open data and private data available in the data marketplace?

When having both free open data and data for sale in the data marketplace, it is important to have a good filter function to allow the buyers to filter the search based on their needs. The initial user testing sessions showed that the naming in the menu bar should cover both buying and selling data, in addition to finding and uploading free open data. Therefore the text in the menu of the final proposed prototype are "search" and "upload" instead of "buy" and "sell", since it covers all the cases.

RQ2.4: Do we need one data marketplace for each city or a common platform for several smart cities?

All the experts in the expert evaluations stated that there is a need for a data marketplace for Trondheim, but many stated that there was an even higher need in other cities. It would also be interesting to have a common data marketplace platform for all the cities in Norway, where you could find data from the whole country. The platform data.norge is an example of a platform for open government data from the whole country. The common smart city data marketplace platform could also have functionality for trading data and provide open data for free. This could help make data more accessible and help solve the issue of discovering data from the numerous available data providers.

RQ2.5 Should we use a decentralized or a centralized network type for the smart city data marketplace?

This research question was explored by studying existing papers and platforms related to decentralized and centralized data marketplaces. The findings show that it is also possible to have a partly decentralized data marketplace, where the storage is centralized and you only use smart contracts for paying for the data products. In the first three iterations of the system design, the fully decentralized network type was used, but this was changed in the fourth iteration. The choice of having options for different payment methods would help to allow different kinds of people to use the data marketplace, both technical and less technical users. The

findings from the expert evaluations showed that most of the experts preferred traditional payment methods over crypto currencies, but many also stated that it would be nice to have both options. This was used in the proposed prototype since crypto currencies are becoming more popular and it would be a nice option to have in the future for such a smart city data marketplace.

9.2.3 Research Question 3

RQ3: How can EA modeling and Customer Journeys support the planning and design of a data marketplace prototype?

RQ3 is answered by the researcher's lessons learned from the research process as well as the results from the five expert evaluations of the approaches. The main findings are that it is good to have a toolbox with several kinds of tools when planning a new system, especially when it does not have any predefined requirements or customer. The use of customer journeys was evaluated as very useful and important for the design of the prototype. The EA modeling was also evaluated as positive for the planning and design, since it provides a common standard on how to sketch the system and looks at many different perspectives of a data marketplace. EA modeling is also a thinking tool that makes it easier to understand the whole system and consider all the important aspects from different perspectives.

RQ3.1 What is the existing work on EA modeling for Data Marketplaces?

As mentioned in chapter 2, there are no prior research on EA modeling of data marketplaces. Therefore this master's thesis contributes with research that helps fill this research gap. It also provides evaluations of using the EA modeling approach for planning and designing a data marketplace. Furthermore the thesis propose an EA model of a the smart city data marketplace that can be used as a blueprint for stakeholders that wants to build such a system in other smart cities.

RQ3.2: What is the benefit or added value of using EA modeling and customer journeys in the design of data marketplaces?

RQ3.2 was answered by the researcher's experiences with using the two approaches, in addition to results from the evaluations of the EA modeling and customer journeys approaches in the Final Evaluations and Results chapter 8.

As mentioned in chapter 2, there are many different EA frameworks, and the +CityxChange framework is a good fit for a smart city data marketplace, since it was developed to model systems in smart cities, as well as focusing on the data layer of a system. The focus on data is extra relevant for a data marketplace since understanding the characteristics of the data and the data sources are crucial for developing a good platform for trading such a product.

The researcher's experiences from using EA modeling for planning and designing the data marketplace were that the use of the services layer, data layer, technologies layer and data sources layer were very important to understand the system of a data marketplace. The business layer was also important to understand and clarify the type of business models and actors to choose for the smart city data

marketplace. The use of EA modeling helped to think and plan for aspects that might otherwise be forgotten or be less investigated. It is a beneficial tool to better understand the whole system from many different perspectives. The use of customer journeys were very beneficial and helpful for understanding the system from a user's perspective for the researcher. It helped plan what features and pages that needed to be designed in the platform and how the different functionalities work together. The customer journeys helped visualise all the steps that a user needs to take to do a specific task in the data marketplace. By showing the steps in a diagram it was easier to spot the steps that were unnecessary or too long etc. The approach was crucial to understand the system from a user's perspective and ensure good user experience.

The customer journeys also influenced the services layer of the EA model, since changes in the customer journeys lead to changes in the EA model and the other way around. For instance when the EA model was changed to have both smart contracts and traditional payment methods, the customer journeys for buying a dataset needed to be updated. The customer journeys and EA models can be found in the system design iterations chapters 4-7.

RQ3.3: How can EA modeling be used to show stakeholders with multiple roles in different scenarios?

The case of modeling stakeholders with multiple roles was not found in other cases that were modelled with the +CityxChange EA framework in the project. The proposed EA model in Final Evaluations and Results chapter 8 shows how the researcher has modeled stakeholders with multiple roles, such as the prosumer which uses the data marketplace for both selling and buying data and potentially also finding and uploading free open data. The multiple roles were shown with extra boxes and arrows from the original stakeholder box.

RQ3.4: How to model all the elements of a data marketplace such as the decentralized network type, data sources, data types, technology stack, business organisations etc with EA?

The literature review showed the existing solutions, trends, challenges, state of the art, background study of data marketplaces which provided information for both the development of the EA models, service design and the prototyping. The EA modeling of some existing data marketplaces provided better understanding of how to use the +CityxChange EA framework, how the whole systems work and all the different aspects related to business, goals, security, stakeholders and data etc.

The EA modeling helped with decision making of which functionalities, technologies, business models and services were needed for the smart city data marketplace. The service design provided a way to easy visualize the different customer journeys, to see steps that were unnecessary and make an easier user experience and still keep all the important steps. Inspiration from the double diamond process helped by providing a structured approach with 4 phases with sub tasks to go from idea and exploration to finished product (the prototype). Both the literature review, EA modeling, service design and double diamond approach

helped design the prototype.

9.3   Discussions Related to Research Questions

In this section, the answers to the research questions are discussed with respect to the feedback from the evaluations and the findings from the literature.

The user testing sessions of the first and second iteration (Chapter 4 and 5) provided findings related to improvement suggestions for the requirements and design of the data marketplace.

The most common improvement suggestions from all the iterations were related to the metadata, possibility to check the quality of the data, good descriptions and enough relevant info about the datasets, functionality for requesting a dataset and possibility for both traditional and crypto payments methods.

The need for good relevant metadata fits very well with the statement that metadata is the most important aspect for selling data from the paper by Lawrenz [12]. This finding from the expert evaluations extend this theory and suggests aspects that has extra importance and relevance, such as last updated and number of data points and null-values.

The findings also showed that the level of usefulness of the system rely very much on whether or not there are much and high quality data on the platform. Here the challenge that quality is always objective is very relevant and the data quality will always depend on the specific buyers requirements, as also stated in the paper by Lawrenz [12].

The use of rating and reviews are something that might give an indication of the quality of the data, but it will still depend on the buyers requirements if it is a high quality dataset for them. The possibility to download a test dataset was stated to be positive for checking the quality of the dataset. Metadata was the most important factor for assessing the quality and relevance of the dataset for the buyer. The experts also liked the page with suggested use cases for how to use the dataset. It was also suggested to have examples of how other buyers had used it to show real-life relevance (success stories).

The use of smart contracts and possibilities to pay with crypto currencies was something that most of the experts said was fine to have both options, since it will probably be more crypto currencies in the future. Most of the experts stated that they would prefer traditional payment methods pr. today and were a bit sceptical to crypto currencies. This evaluation of opinions towards smart contracts and decentralized data marketplaces has not been covered in the literature such as the i3, Datapace and Wibson papers, and this thesis provide new data on the topic. This can be expanded on for future work to conduct a survey and market analysis on the opinions and willingness to use smart contracts and crypto currencies in data marketplace today. The design of the partly decentralized data marketplace with options for smart contracts makes room for use in the future when the market may have matured.

The ease of use of the proposed prootype was evaluated at high level by the experts, which indicates that the data marketplace was easy to navigate and use. This is important for any kind of user interface, but some of the experts stated that it was not the most important factor but something they still would expect in a platform for sale of data, but not so much for an open data portal.

The experts evaluated the likeliness to use the platform for selling data professionally as high. This is probably since they work with data daily, in their roles as researches, PhD candidates, machine learning or data analysts. There were more experts that would use the platform to buy data than sell data.

The findings from this research project extends prior related papers with more data on needs of data marketplaces for smart cities. For instance it extends the master thesis by Välja et al. since the paper did not design or implement a prototype of the data marketplace of the smart city Stockholm [27]. The proposed data marketplace prototype, EA model and the requirements of the master thesis can be used by different smart cities, including Stockholm. The new prototype helps fill the research gap of Norwegian data marketplaces, by adding more literature and findings on the topic to the body of literature.

There is also many papers that focus on using EA modeling for modeling smart city systems, and this project extends these papers with a new angle of data marketplaces and smart city data marketplaces that has not yet been investigated.

9.4 Data Marketplaces and UN Sustainable Development Goals

This section includes discussions of how the smart city data marketplace can be related to the UN Sustainable development goals [70].

The UN Sustainable development goals consist of 17 goals for the world, and it was important to have them in mind when planning the data marketplace [70]. Goal number 11 related to sustainable cities and communities are relevant for this master's thesis since it focus on smart cities. The master's thesis is also is relevant for goal 9 that focus on industry, innovation and infrastructure.

The proposed smart city data marketplace can help achieve the UN Sustainable development goals, since the platform makes data more accessible. The data marketplace aims to make it easier to share and use the enormous amounts of data that is generated each day for something productive. The smart city data marketplace has the goal to help make new value-adding services and innovations that can improve the lives of the citizens of the smart city. This is done by providing an open data marketplace platform where it is easy for both technical and less technical people to sell, buy, share and get access to data.

The use of smart contracts and crypto currencies have the disadvantage that they use very much energy. The blockchain Etherium that the smart contract for this project could be built upon uses less energy than other blockchains, but it is still an important issue to discuss in relation to sustainability. On the other hand

smart contract limits the use of paper for contracts, and the automatic nature of the smart contract limits the need for third parties and the number of people that needs to work in order to process the contract. In this way the smart contract has both positive and negative effects for the environment.

This project shows possible solutions for a design of a smart city data marketplace, and it is easy to take away aspects like smart contracts if the future project owner would like to only have traditional payment methods. The proposed prototype have options for both traditional payment methods and smart contracts with crypto currencies.

The proposed prototype does not have a decentralized storage of the data, since it would make it less stream lined for the customers, and cause an even higher need for energy. This means that the prototype is a partly decentralized system, which has some of the benefits of the decentralized technologies and keeps most of the benefits of the centralized platform.

9.5 Lessons Learned

This section includes reflections of the lessons learned from the research project, and it discusses the different approaches and methods used and lessons learned from using them.

Literature Review

The research project experience showed the researcher the great importance of studying prior related papers, existing platforms and technologies before designing a data marketplace. The researcher had no prior experience or knowledge of data marketplaces, and the literature review was very helpful to understand the concepts and data trading landscape. This was crucial to be able to plan and design a data marketplace for the smart city Trondheim. Since there were no predefined requirements for the system it was extra important to continuously return to literature through all the iterations of the project to get more clarifications of details, understand technologies and state of the art. Specially the decentralized aspects such as the smart contracts was complicated and very important to understand to be able to design and make decisions based on existing solutions. Therefore many of the studied papers involved decentralized data marketplaces.

EA modeling The researcher had some prior knowledge of EA from the course TDT4252 that focuses on EA modeling. The course did not cover the +CityxChange EA framework that was used in this research project. It was very interesting to get a broader and in depth understanding and more hands-on experience of EA modeling by using it as one of the methods in the research process, as well as learning about the new +CityxChange EA framework. The framework was well suited to the case of the smart city data marketplace, since it covered many different aspects of the system, as well as focusing on the data layers which is crucial for a data marketplace. The use of EA modeling was beneficial to understand the whole system and all the components and processes.

Service Design and Customer Journeys

The researcher did not have any prior experience with customer journeys, but was familiar with developing user stories which is a bit similar to customer journeys, since it shows what a user expects to be possible to do in a specific scenario in the system. The customer journeys were very helpful to use in the planning process since they showed all the steps that a user needs to take to go through a task in the system. This is a method that is very beneficial to have knowledge of and that can be used in future career projects.

Figma Prototyping The researcher did not have any prior experience with Figma prototyping. Therefore it was a steep learning curve for understanding how to use the Figma tool and design the different views based on the customer journeys. Figma is often used by UX developers in IT companies, and the experience and knowledge of Figma prototyping is something that is very beneficial for the research's future career projects. Figma is also helpful for understanding flows, usefulness, ease of use and good user experience, as well as looking in to planning how the whole system works together by the help of EA modeling.

User Testing It was a new experience for the researcher to conduct user testing sessions online instead of physical meetings that was used in previous projects in NTNU courses. The use of Microsoft Teams made the process very easy and the integrated functionalities for audio and video recordings were very helpful to streamline the meetings. On the other hand, online meetings made it more difficult to observe body language and the meetings were more prone to technical issues. In general the online user testing sessions was very successful and it is something the researcher will continue to use for user testing in future projects.

9.5.1 Summary

This chapter has described the novelty of the prototype, how the findings help address the research questions, discussions related to the research questions, data marketplaces and UN sustainable development goals and the lessons learned from the master's thesis.

Chapter 10

Conclusion

This chapter describes the summary of the master's thesis, the contributions, limitations and future works for the project.

10.1 Summary

This section includes a summary of the report and the research project.

The thesis has provided new insight to what a data marketplace actually is and has shown how experts in the field would describe a data marketplace. It has also proposed a definition of a data marketplace and a smart city data marketplace, since there is no widely used definitions in academic papers. The thesis has defined the concepts in the following way:

"A data marketplace is a digital platform for easy selling, buying and sharing of data."

"A smart city data marketplace is a digital platform for easy selling, buying and sharing of data, that mainly come from smart city data sources such as Internet of Things (IoT) sensors, citizen and business data from the smart city."

The report has provided an overview of the types, characteristics, trends and challenges of the current data marketplaces. The thesis has also explored and identified what is needed in a smart city data marketplace, and used EA modeling and Service design approaches to design a prototype of how such a system could look like. The four iterations of the prototype can be found in chapter 4-7 and the final proposed prototype in chapter 7.

The thesis provided a proposed smart city data marketplace prototype that received an average rating of high level of ease of use from the expert evaluations. The average rating of the usefulness was also evaluated as high level. The thesis has provided answers from experts of different domains in the smart city, that back the claim that there is a need for a smart city data marketplace in smart cities like Trondheim. All the experts in the evaluations stated that there was a need for such a platform and that they would recommend the platform to others. The final evaluations of the proposed prototype provided interesting suggestions for improvements that can be designed in future work of the research project.

Furthermore, the research has investigated how and why to choose a decentralized or centralized data marketplace for smart cities. The thesis has explained why it is more beneficial for the data marketplace to have a semi decentralized platform, with options for both smart contracts and traditional payment methods, and a centralized storage. The semi decentralized network type was chosen primarily, since it allowed the design to partly follow the trend towards decentralized platforms, and still make it easy for both technical and less technical users to buy and sell data.

The evaluations by several experts provided us with data necessary to back the claim that EA modeling and customer journeys are useful approaches for planning and designing a data marketplace. The thesis has also explored how to model a data marketplace with EA modeling, and proposed an EA model of the smart city data marketplace. It can be used as a blueprint to develop new data marketplaces in the future.

The thesis work has been very interesting as well as challenging. It has been a good way to learn and experience the importance of how to manage the time and plan an independent research project. The project included many aspects that were new to the researcher, for instance using the tool Figma for designing the prototype, conducting literature reviews, EA modeling with the +CityxChange framework and conducting expert evaluations with external experts in the field. The research project has provided many new experiences and lessons on how to conduct research, specify research questions and objectives, research methods and strategies to be able to answer the research questions in a suitable manner. It has been a very interesting project and the experiences and lessons learned will be highly valuable for future career and IT projects.

10.2   Contributions

This section includes the contributions and implications of the research project.

The master's thesis contributes with more research results related to the study areas smart city data marketplaces, EA modeling and Service design of data marketplaces. The main contributions of the research project are five fold; (1) the design of the smart city data marketplace, (2) the proposed smart city data marketplace Figma prototype, (3) the design method of using EA modeling and Service design approaches for designing the smart city data marketplace, (4) the proposed EA model of the smart city data marketplace and (5) the proposed definitions of a data marketplace and smart city data marketplace.

The number one contribution of the thesis are the design of the smart city data marketplace and the proposed Figma prototype. The design includes the contributions of requirement specifications, developed personas, customer journeys and EA model of the smart city data marektplace. These can be used as inspiration for developing new data marketplaces. The proposed smart city data marketplace prototype can help solve some of the challenges in the data trading landscape, including quality of data, trust, ease of use and discoverability. The numerous hours

of expert evaluations and user testing sessions have also resulted in a thoroughly user tested prototype with focus on the ease of use and needs of the users. The total list of requirements are also a contribution of the master's thesis and can be found in the Final Evaluations and Results chapter 8.

Secondly the thesis contributes with a proposed EA model and customer journeys for the new data marketplace. These can be used as a blueprint and road map for implementing a data marketplace for Trondheim or other smart cities. The methods of combining the two disciplines of EA modeling and Service design to plan and design a data marketplace is also a novel contribution of the thesis.

Last but not least, the contribution of the new proposed definition of a data marketplace can be beneficial for future academic papers, since currently there is no commonly agreed definition of the concept.

The findings and contributions from the project can be beneficial for other master's thesis projects that can extend this research project. The contributions are also beneficial for the +CityxChange project, since the partners in the project can use the EA models as a blueprint to develop data marketplaces in the smart cities to foster new services for their citizens.

10.3   Limitations

This section includes the limitations of the research project.

A limitation of the research is that there can be sources of errors when comparing the results from the third and fourth iteration, since there were a different number of experts in the iterations. It would have been beneficial to have a more equal number of experts in each iteration, but unfortunately it was not possible to get more than three experts in the fourth iteration.

Another limitation is that there were only few participants in the evaluations with less technical experience. It would be beneficial to test the proposed prototype on several less technical users to check if the level of ease of use and usefulness would still be high. Another limitation was the difference in the representation of gender of the participants in the evaluations. It would also be interesting to have a more even representation of genders. These limitations should be considered in possible continuations of the research project by new master's students.

10.4   Future Works

This section includes the identified future works of the research project.

The future works and next steps of the research project would be to start implementing the fullstack web application with both a frontend and backend, cloud storage, APIs, etc. As mentioned in the contributions section, the proposed EA model of the smart city data marketplace can be used as a blueprint for developing the data marketplace. It shows the technical aspects that need to be considered

for the fullstack web application and suggestions for possible choices of technologies, frameworks (Angular and React), cloud storage (Microsoft Azure), etc. As mentioned in the literature review chapter, the open source smart contract developed by i3 could also be used for the platform [14]. The fullstack development of the data marketplace will need a team of both systems architecture experts, database, backend, frontend developers, testers and designers to further develop the system iteratively.

This research project encourages further research, design, user testing and implementation of the data marketplace for smart cities like Trondheim. The master's thesis has shown that there is a need for such platforms and that there is room for further research in this area. The expert evaluations from the third and fourth iteration showed several suggestions for improvements that were evaluated as nice or must have for future works. The total list of requirements includes these suggestions and can be found in the Final Evaluations and Results chapter 8. Furthermore, the requirements specifications, as well as the EA models, customer journeys and design prototype can be used by future master's students who can build on this work or developers of a data marketplace for Trondheim or other smart cities.

The focus on policies and GDPR was not a part of the scope of this thesis, but there is room for future work to include good policies and ensure privacy in the data marketplaces. The master's thesis by Ulversøy et al. focuses on preserving the privacy of an individual in a fully decentralized data marketplace [19]. This area is new and there is a need for further research.

There is also need for more research on the topics of life cycle of data in data marketplaces and exploring the different views of stakeholders and perspectives more thoroughly. The topics of how to improve the descoverability of data and how to make it easier to evaluate the quality and relevance of data in a data marketplace are also very important topics and need more research. Furthermore, there is also room for more research on how to make decentralized platforms easy to use also for less technical people. These topics are identified as important for future work.

The literature review showed that there are few academic papers that explores the trends and challenges of data marketplaces. There are several aspects of data marketplaces that could be explored further, and since the survey papers by Stahl et al. are from 2012 and 2014, they are somewhat outdated and there is room for new and updated surveys on the data trading landscape in general [9]. This thesis shows some of the new trends in the landscape such as smart contracts, but it would be interesting for future research to explore the new trends in the area in more depth.

It would also be interesting to conduct a thorough market analysis of the potential users of the data marketplace in Trondheim. This could also include questions related to preferred payment methods, use of smart contracts and crypto currencies. To have enough buyers and sellers are crucial for a data marketplace to function and therefore a market analysis would be an interesting and important

factor for future research to ensure use of the new platform.

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Appendix A

Figma Prototype

Appendix A includes the link to the Figma prototype of the smart city data marketplace from the fourth iteration of the project.

Click on this link to get access to the Figma prototype

Appendix B

Slides from Experts Evaluations

Appendix B includes the slides from the expert evaluations in the third and fourth iteration of the master's thesis.

Enterprise Architecture for Data Markets to Support Service-based Ecosystems in Smart Cities

User Testing

Rebekka Alvsvåg, Informatics MSc

Demographics

- What age group do you belong to?   (20-29, 30-39, 40-49, 50-59, Above 60 years)

- Are you a Trondheim Citizen?

- What is your occupation?

- Do you work with data or open data?

- Have you used a data marketplace or a open data portal before?

Prior Knowledge

The Likert scale: 1= Very low level   2= low level   3= neutral   4= high level   5= very high level

- What is a data marketplace and a smart city data marketplace? Describe it in your own words (open ended)

- How would you evaluate your prior knowledge level of data marketplaces? (1-5)

- How would you evaluate your prior knowledge level of user testing? (1-5)

- How would you evaluate your prior knowledge level of design prototyping? (1-5)

- How would you evaluate your prior knowledge level of system development? (1-5)

User Testing of Prototype

- Important to think aloud

- The goal is to test the prototype and not to test you

- User stories
  - i.e "As a user you should find data related to weather and select the TW Temperature dataset"

- Feedback during and after the user testing

Feedback

- Would you prefer using traditional payment methods or cryptocurrencies in the smart city data marketplace?

- Is there something missing that you would like to have in a data marketplace for smart cities like Trondheim?

Feedback: Perceived Usefulness

The Likert scale: 1= Very low level   2= low level   3= neutral   4= high level   5= very high level

- How would you evaluate the usefulness of the prototype? (1-5)

- What did you find the most and least useful with the prototype? (open ended)

Feedback: Ease of use

The Likert scale: 1= Very low level   2= low level   3= neutral   4= high level   5= very high level

- How would you evaluate the ease of use of the prototype? (1-5)

Feedback: Intention to use

The Likert scale: 1= Highly unlikely   2= not likely   3= neutral   4= likely   5= very likely

- Would you use the smart city data marketplace for buying data? (1-5)
  - professional/private
- Would you use the smart city data marketplace for selling data? (1-5)
  - professional/private

- Would you recommend using the smart city data marketplace to others? (1-5)

- Do you see a need for a data marketplace for the smart city Trondheim? (open ended)

- In which scenarios would the smart city data marketplace for Trondheim be useful? (open ended)

Thank you for your participation!

User Testing of Prototype

Enterprise Architecture for Data Markets to Support Service-based Ecosystems in Smart Cities

Evaluation of the EA modelling & Customer Journeys Approaches

Rebekka Alvsvåg, Informatics MSc

Prior Knowledge

The Likert scale: 1= Very low level   2= low level   3= neutral   4= high level   5= very high level

- How would you evaluate your prior knowledge level of **data marketplaces**? (1-5)

- How would you evaluate your prior knowledge level of **user testing**? (1-5)

- How would you evaluate your prior knowledge level of **system developmen**t? (1-5)

- How would you evaluate your prior knowledge level of **Enterprise Architecture modelling**? (1-5)

- How would you evaluate your prior knowledge level of **customer journeys**? (1-5)

EA modelling & Customer Journeys


The Process

- **Double Diamond**
  - (4 phases: discover, define, develop, deliver)

- **Litterature Review**
  - & background study of existing platforms

- **EA modelling & Customer journeys**

- **Figma prototyping** w/ user testing

- **Iterative process**

1. Discover   2. Define   3. Develop   4. Deliver
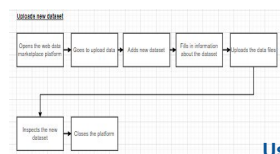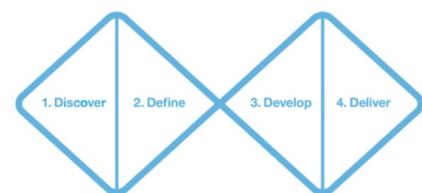
User Testing of Prototype

Customer Journeys

- Shows the steps that the customer needs to go through (i.e tasks for uploading a dataset)
- Changed within the iterations
- Based on findings from Literature review, expert feedback & EA modeling
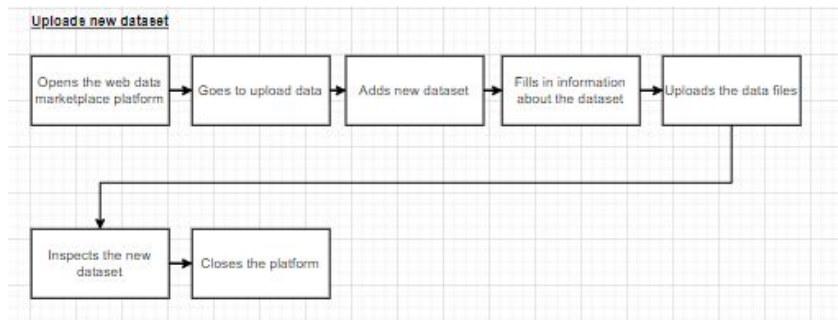
The Enterprise Architecture Modelling

- Used the +CityxChange EA framework

- Used 7 horizontal layers + 2 of the vertical perspectives

- Shows the system from different perspectives, i.e technology and business

- **Do you have any comments or suggestions for improvements of the EA model? (open ended)**

- **Do you think this EA model shows all the important aspects of a data marketplace for Trondheim? (open ended)**
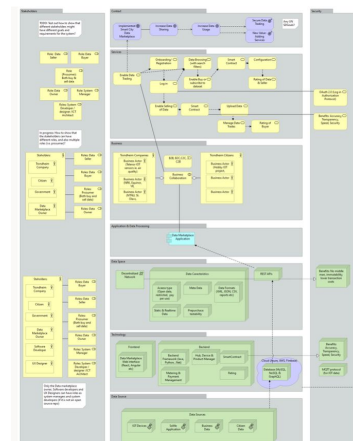
Feedback: Perceived Usefulness

The Likert scale: 1= Very low level   2= low level   3= neutral   4= high level   5= very high level

- How would you evaluate the usefulness of the **EA modelling** approach for planning and designing a data marketplace? (1-5)

- To what extent do you think the **EA modelling** is easy to understand for you? (1-5)

- What do you find the most and least useful/positive with **EA modelling** for planning and designing a data marketplace? (open ended)

Feedback: Perceived Usefulness

The Likert scale: 1= Very low level   2= low level   3= neutral   4= high level   5= very high level

- How would you evaluate the usefulness of the **customer journeys** approach for planning and designing a data marketplace? (1-5)

- To what extent do you think the **customer journeys** is easy to understand for you? (1-5)

- What do you find the most and least useful/positive with **customer journeys** for planning and designing a data marketplace? (open ended)

Feedback: Perceived Usefulness

The Likert scale: 1= Very low level   2= low level   3= neutral   4= high level   5= very high level

- How would you evaluate the usefulness of combining the **EA modelling and customer journeys** approaches for planning and designing a data marketplace? (1-5)

- What do you find the most and least useful/positive with combining the **EA modelling and customer journeys** approaches for planning and designing a data marketplace? (open ended)

Thank you for your participation!

Appendix C

NSD Notification Form

Appendix C includes the NSD notification form for processing privacy information in the research project.

∿ NORSK SENTER FOR FORSKNINGSDATA

Meldeskjema 968843

Sist oppdatert

14.03.2021

Hvilke personopplysninger skal du behandle?

- Navn (også ved signatur/samtykke)
- E-postadresse, IP-adresse eller annen nettidentifikator
- Bilder eller videoopptak av personer
- Lydopptak av personer
- Bakgrunnsopplysninger som vil kunne identifisere en person

Type opplysninger

Du har svart ja til at du skal behandle bakgrunnsopplysninger, beskriv hvilke

Bakgrunnsopplysninger som skal behandles er; navn på firmaer, navn på eksperter, stilling, tilhørighet til Trondheim, kunnskapsnivå

Skal du behandle særlige kategorier personopplysninger eller personopplysninger om straffedommer eller lovovertredelser?

Nei

Prosjektinformasjon

Prosjekttittel

Enterprise Architecture for Data Marketplaces to Support Service-based Ecosystems in Smart Cities

Prosjektbeskrivelse

Informatics Master thesis project at the Norwegian University of Science and Technology. The purpose of the project is to develop an enterprise architecture model for a data marketplace for smart cities, and develop a design prototype for such a platform.

Begrunn behovet for å behandle personopplysningene

Det er behov for å lagre lydopptak for å kunne høre gjennom diskusjoner og tilbakemeldinger fra focus grupper etter at de er ferdig, samt video for å kunne analysere hvordan brukere reagerer på user testing av prototype. Det er behov for lagring av info som tittel/stilling og navn da dette kan være med på å begrunne relevansen og valget av deltagere til evaluering av prosjektet. E-poster vil også bli lagret da dette trengs for å kunne avtale tidspunkter for fokusgruppe, user testing etc.

Ekstern finansiering

Type prosjekt

Studentprosjekt, masterstudium

Kontaktinformasjon, student

Rebekka Alvsvåg, rebekal@stud.ntnu.no, tlf: 90555647

Behandlingsansvar

Behandlingsansvarlig institusjon

Norges teknisk-naturvitenskapelige universitet / Fakultet for informasjonsteknologi og elektroteknikk (IE) / Institutt for datateknologi og informatikk

Prosjektansvarlig (vitenskapelig ansatt/veileder eller stipendiat)

Sobah Abbas Petersen, sap@ntnu.no, tlf: 92846595

Skal behandlingsansvaret deles med andre institusjoner (felles behandlingsansvarlige)?

Nei

Utvalg 1

Beskriv utvalget

Utvalg av studenter og ansatte fra NTNU, samt innbyggere i Trondheim til brukertesting av design prototype (data marked for smart byen Trondheim)

Rekruttering eller trekking av utvalget

Fra eget og veileders nettverk

Alder

19 - 60

Inngår det voksne (18 år +) i utvalget som ikke kan samtykke selv?

Nei

Personopplysninger for utvalg 1

- Navn (også ved signatur/samtykke)
- E-postadresse, IP-adresse eller annen nettidentifikator
- Bilder eller videoopptak av personer
- Lydopptak av personer
- Bakgrunnsopplysninger som vil kunne identifisere en person

Hvordan samler du inn data fra utvalg 1?

Annet

Beskriv

Brukertesting av design prototype, hvor det tas notater av tilbakemeldinger og observasjoner underveis

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (art. 6 nr. 1 bokstav a)

Informasjon for utvalg 1

Informerer du utvalget om behandlingen av opplysningene?

Ja

Hvordan?

Skriftlig informasjon (papir eller elektronisk)

Utvalg 2

Beskriv utvalget

Fokusgruppe med utvalg av ansatte og studenter på NTNU, samt representanter fra relevante bedrifter til evaluering av design prototypen, Enterprise Architecture modellen for datamarkedet og selve Enterprise Architecture metoden

Rekruttering eller trekking av utvalget

Fra eget og veileders nettverk

Alder

19 - 60

Inngår det voksne (18 år +) i utvalget som ikke kan samtykke selv?

Nei

Personopplysninger for utvalg 2

- Navn (også ved signatur/samtykke)
- E-postadresse, IP-adresse eller annen nettidentifikator
- Bilder eller videoopptak av personer
- Lydopptak av personer
- Bakgrunnsopplysninger som vil kunne identifisere en person

Hvordan samler du inn data fra utvalg 2?

Annet

Beskriv

Fokusgruppe for evaluering av design prototype, Enterprise Architecture modell av datamarkedet og Enterprise Architecture metoden

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (art. 6 nr. 1 bokstav a)

Informasjon for utvalg 2

Informerer du utvalget om behandlingen av opplysningene?

Ja

Hvordan?

Skriftlig informasjon (papir eller elektronisk)

Tredjepersoner

Skal du behandle personopplysninger om tredjepersoner?

Nei

Dokumentasjon

Hvordan dokumenteres samtykkene?

- Elektronisk (e-post, e-skjema, digital signatur)

Hvordan kan samtykket trekkes tilbake?

Ved å kontakte prosjektansvarlig Sobah Abbas Petersen via mail som er oppført på informasjonsskrivet.

Hvordan kan de registrerte få innsyn, rettet eller slettet opplysninger om seg selv?

De lagrede opplysningene blir vist til vedkommende og slettet eller rettet ved forespørsel.

Totalt antall registrerte i prosjektet

1-99

Tillatelser

Skal du innhente følgende godkjenninger eller tillatelser for prosjektet?

Behandling

Hvor behandles opplysningene?

- Ekstern tjeneste eller nettverk (databehandler)

Hvem behandler/har tilgang til opplysningene?

- Student (studentprosjekt)
- Prosjektansvarlig
- Databehandler

Hvilken databehandler har tilgang til opplysningene?

Microsoft Teams og One Drive blir brukt til å lagre informasjon om prosjektet samt til bruk av digitale møter.

Tilgjengeliggjøres opplysningene utenfor EU/EØS til en tredjestat eller internasjonal organisasjon?

Nei

Sikkerhet

Oppbevares personopplysningene atskilt fra øvrige data (koblingsnøkkel)?

Ja

Hvilke tekniske og fysiske tiltak sikrer personopplysningene?

- Adgangsbegrensning

Varighet

Prosjektperiode

15.02.2021 - 01.06.2021

Skal data med personopplysninger oppbevares utover prosjektperioden?

Nei, alle data slettes innen prosjektslutt

Vil de registrerte kunne identifiseres (direkte eller indirekte) i oppgave/avhandling/øvrige publikasjoner fra prosjektet?

Ja

Begrunn

Professorer og eksperter for evaluering vil være identifiserbar i form av navn, stillingstittel og kunnskapsfelt for å kunne vise relevans for utvalget av deltagere i evalueringsprosessen av prosjektet. Aldersgruppe, yrke, navn på bedrifter, studenter eller ansattes tilknytning til NTNU og Trondheim vil også være direkte beskrevet i masteroppgaven for å begrunne relevans for utvalget og resultatene.

Tilleggsopplysninger

Rebekka Alvsvåg

A Concept for Smart City Data Marketplace using Enterprise Architecture and Service Design Approaches

NTNU
Norwegian University of
Science and Technology