Master's thesis

NTNU
Norwegian University of Science and Technology
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Department of Computer Science

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Motivating Positive Environmental Behaviour Change for Sustainable and Inclusive Cities: A Study on Mobile Application Design and Gamification

Master's thesis in Computer Science
Supervisor: Letizia Jaccheri
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Abstract

Urgent action is needed to address the global threat of climate change. The European Green Deal aims for net zero greenhouse gas emissions by 2050, with inclusion as a priority. Sustainable, visually appealing urban solutions are emphasized by the New European Bauhaus initiative and the European Union (EU) Cities Mission. Smart cities, driven by advanced technology, offer promising solutions, and inclusive digital solutions should be developed and studied to contribute to achieving these goals.

In this project, we aim to explore how a digital platform should be designed to motivate citizens towards positive environmental behaviour change for a sustainable and inclusive city. We also investigate the use of gamification to encourage environmental behaviour change. The research objective was established based on the findings of a Systematic Literature Review (SLR) conducted in the autumn of 2022. The following research questions were formulated, which guide the study:

RQ1: How should a digital platform be designed to motivate citizens to contribute to a sustainable and inclusive city?

RQ2: Which specific gamification elements should be implemented in such a digital platform to make citizens change environmental behaviour?

To answer the RQs, a mobile application prototype has been developed, following the design and creation research strategy. The data generation methods used as part of the research project were a focus group interview, usability testing, observation, and a questionnaire, namely the System Usability Scale (SUS).

The focus group interview and usability testing yielded key insights for our mobile application prototype. Motivational aspects, including network features and competition, guided the application's requirements. Usability testing results, with SUS scores of 80.7 and 86.1 for Iteration 1 and Iteration 2 respectively, confirmed the effectiveness of the design and highlighted the impact of different gamification elements on user motivation.

The thesis concludes that gamification elements, such as challenges, badges, points, and leaderboards, effectively motivate citizens to change their environmental behaviour. By tailoring the design to individual preferences, social aspects, and promoting inclusivity, the digital platform can have a significant impact on motivation and behaviour change. This study provides valuable insights for designing effective digital platforms for sustainable and inclusive cities.

Sammendrag

Klimaendringer utgjør en global trussel som krever øyeblikkelig handling. EUs grønne vekststrategi - "European Green Deal", har som mål å oppnå netto nullutslipp av klimagasser innen 2050, med inkludering som en prioritet. Initiativer som *New European Bauhaus* og *EU Cities Mission* legger vekt på bærekraftige og estetisk tiltalende byløsninger. Smarte byer, som er drevet av avansert teknologi, gir lovende muligheter, og utvikling av inkluderende digitale løsninger er viktig for å oppnå disse målene.

I dette prosjektet undersøker vi hvordan man bør designe en digital plattform som kan motivere innbyggere til positiv endring av miljøatferd og bidra til en bærekraftig og inkluderende by. Vi undersøker også bruken av spillifisering for å motivere til endring av miljøatferd. Målene for prosjektet ble etablert basert på funnene fra et systematisk litteraturstudie gjennomført høsten 2022. Følgende forskningsspørsmål ble formulert, og veileder forskningsprosjektet:

FS1: Hvordan bør en digital plattform utformes for å motivere innbyggere til å bidra til en bærekraftig og inkluderende by?

FS2: Hvilke spesifikke spilldesign-elementer bør implementeres i en slik digital plattform for å få innbyggere til å endre miljøatferd?

For å svare på forskningsspørsmålene har vi utviklet en prototype på en mobilapplikasjon, i tråd med forskningsstrategien "Design and creation". Vi har benyttet oss av et fokusgruppeintervju, brukervennlighetstesting, observasjon og et spørreskjema, kalt SUS, som datainnsamlingsmetoder i prosjektet.

Fokusgruppeintervjuet og brukervennlighetstestingen ga viktig innsikt for vår mobilapplikasjonsprototype. Motivasjonsaspekter, inkludert sosiale aspekter og konkurranseelementer, veiledet kravene til applikasjonen. Resultatene fra brukervennlighetstestingen, med SUS-poengsum på henholdsvis 80,7 og 86,1 for Iterasjon 1 og Iterasjon 2, bekreftet effektiviteten av designet og viste virkningen av forskjellige spilldesign-elementer på brukernes motivasjon.

Oppgaven konkluderer med at spilldesign-elementer, som utfordringer, emblemer, poeng og topplister, effektivt motiverer innbyggere til å endre sin miljøatferd. Ved å tilpasse designet til individuelle preferanser, sosiale aspekter og fremme inkludering, kan den digitale plattformen ha betydelig innvirkning på atferdsendring. Denne studien gir verdifulle innsikter for utforming av effektive digitale plattformer for bærekraftige og inkluderende byer.

Acknowledgement

We would like to express our deepest appreciation to Professor Letizia Jaccheri and PostDoctoral Researcher Alicia Julia Wilson Takaoka for their supervision during the entire project process. They have both contributed with their expertise in Computer Science research. Jaccheri has been the main supervisor, and we are grateful for all the help, knowledge and support she has shared during the entire project process. Takaoka has been the co-supervisor, providing us with extensive feedback and guidance every week, which has given much value to the project. We are also grateful for the valuable feedback received from PhD Candidate Ibrahim El Shemy. We would also like to thank all members of the research group Software for a Better Society (SBS) at the Norwegian University of Science and Technology (NTNU) for all the weekly educational meetings the last year, where we got to share concerns and gather valuable knowledge on research.

Many thanks to Alicia Julia Wilson Takaoka, Dirk Ahlers and Letizia Jaccheri as our co-authors on the paper *Towards understanding digital tools contributing to climate neutral, inclusive, and beautiful cities - A systematic literature review* [1]. Special thanks go to main author Alicia Julia Wilson Takaoka who presented the paper at ICSE GREENS 2023 - an international workshop on green and sustainable software.

Special thanks also go to Professor Leticia Jaccheri for facilitating two academic travels the past year, namely the conference *Association for Computing Machinery (ACM) womENcourage 2022* in Larnaca, Cyprus, and the workshop *Wonders: Workshop on Diversity in STEAM* in Manaus, Brazil through the Software Engineering Norway Brazil (SENOBR) project. Thanks to the Grupo de Pesquida em USabilidade e Engenharia de Software (USES) Universidade Federal do Amazonas (UFAM) research group in Brazil for the warm welcome, and educational week in Brazil. These journeys have provided us with invaluable learning experiences in the realm of research, allowing us to connect with fellow academics and expand our knowledge. These trips have had a positive impact on our work, enriching our understanding and offering new perspectives. Thanks also to the organisers and fellow participants of the Autumn school 2022 "URSA MAJOR - Urban Sustainability in the Artic Cities" for providing us with knowledge on urban scenarios toward sustainable city transformation. We are also grateful for Senior Engineer Terje Røsand, who facilitated the use of the User Experience (UX) Lab at NTNU. Lastly, we would like to thank all our participants for their valuable contribution.

Preface

This thesis is part of the TDT4900 - Computer Science, Master's Thesis course at the NTNU. Professor Letizia Jaccheri was the main supervisor of the research project, assisted by co-supervisor PostDoctoral Researcher Alicia Julia Wilson Takaoka at the Department of Computer Science at NTNU, Trondheim.

The thesis builds on previous work from the course TDT4501 - Computer Science, Specialization Project, resulting in a SLR. The project description for TDT4501 can be found in Appendix A. During the Specialization Project, the authors submitted an extended abstract that was accepted for the ACM-W WomENcourage 2022[1] conference, which the authors also attended. The detailed content of the extended abstract can be accessed in Appendix B.

The paper *Towards understanding digital tools contributing to climate neutral, inclusive, and beautiful cities - A systematic literature review* [1] was accepted and presented at the ICSE[2] GREENS[3] 2023 - an international workshop on green and sustainable software. This paper was published together with the main author PostDoctoral Researcher Alicia Julia Wilson Takaoka, Senior Researcher and research manager with the *NTNU Smart Sustainable Cities* Dirk Ahlers and Professor Letizia Jaccheri.

[1] https://womencourage.acm.org/2022/

[2] https://conf.researchr.org/home/icse-2023

[3] https://greensworkshop.github.io/GREENS2023/

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Acronyms

ACM Association for Computing Machinery. v, vi, 133

AI Artificial Intelligence. 26, 28, 118

CBM Cognitive Bias Modification. 17, 18

CrAFt Creating Actionable Futures. 2, 7, 13, 62

DT Digital Transformation. 1

EU European Union. iii, iv, 1, 2, 6, 7

FBM Fogg Behavior Model. 11, 16–18, 61, 108, 110, 111, 114, 116, 121

HCI Human-Computer Interaction. 17, 28

ICT Information and Communication Technologies. 9, 13

IoT Internet of Things. 26, 28

MVP Minimum Viable Product. 117, 118

NEB New European Bauhaus. 2, 6, 7, 13

NSD Norwegian Centre for Research Data. 32, 147

NTNU Norwegian University of Science and Technology. v, vi, 13, 38, 44, 74, 108

SBS Software for a Better Society. v, 37, 40, 108

SDG Sustainable Development Goal. 2, 4–6, 9

SENOBR Software Engineering Norway Brazil. v, 43

SLR Systematic Literature Review. iii, vi, 2–4, 19–32, 35, 36, 40, 41, 53, 63, 77, 108, 116, 119

SUS System Usability Scale. iii, iv, 32, 35, 42–44, 50–52, 79, 84–90, 107, 112, 113, 117, 120

TTM Transtheoretical Model. 14, 15, 17, 18, 62, 64, 72, 73, 78, 109–111, 114, 115

UFAM Universidade Federal do Amazonas. v, 44

UN United Nations. 2, 4, 8

USES Grupo de Pesquida em USabilidade e Engenharia de Software. v, 43

UX User Experience. v, 11, 43–45, 48, 79, 84, 92, 109, 117

WCAG Web Content Accessibility. 10, 65, 74

Chapter 1

Introduction

The European Commission outlines commitment to tackling climate and environmentally related challenges as the defining duty of our generation. Through the European Green Deal[1] strategy, the commission aims to perform a just and inclusive transformation of the EU community, where zero greenhouse gas emissions are achieved in 2050 and where citizens' health and well-being are protected from environmental-related threats [2]. At the same time, we live in a society that is becoming more and more digitalised, and Digital Transformation (DT) refers to the significant changes caused by the use of digital technologies in both society and industry [3]. Using the potential of DT is essential for Europe to achieve the goals of the Green Deal [2].

The objective of this thesis is to address these issues by increasing individual citizens' motivation to change environmental behaviour through the design and development of a mobile application prototype. We present the findings of a design and creation research strategy, a research strategy focused on the development of new IT artefacts [4], involving the design, development, and evaluation of a mobile application prototype for environmental behaviour change. We also present directions for future research, as we argue that this project could be a building block for further studies on the area. The outline of this chapter is as follows: the motivation of the project is explained in Section 1.1, followed by the description of the project in Section 1.2. Section 1.3 presents the objective of the project and, lastly, Section 1.4 explains the outline of the thesis.

1.1 Motivation

Climate change and its associated environmental challenges pose a profound threat not only to Europe but also to the entire world. As recognised by the European Green Deal, this issue demands urgent action. The Green Deal underscores the necessity of achieving net zero greenhouse gas emissions by 2050 while ensuring

[1] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

that no individual or region is left behind [2]. By the same year, the projected percentage of the world's population residing in urban areas is a staggering 70%, a significant increase from the current amount [5], justifying that the transition of cities to become climate-neutral should be in focus when striving to achieve the goals of the European Green Deal. In addition, the United Nations (UN) has developed 17 Sustainable Development Goal (SDG)s to achieve by 2030[2], including the goal for sustainable and inclusive development of cities. The EU has, through its new component in the Horizon Europe[3], EU Missions[4], set ambitious goals to solve some of the greatest challenges and bring concrete results by 2030. One of these missions, the Mission on Climate-neutral and Smart Cities, highlights the importance of urban action in climate mitigation, also highlighting that European cities can substantially contribute to the Green Deal.

The New European Bauhaus (NEB), an EU initiative connecting the European Green Deal to citizens' living spaces and experiences, calls 'on all of us to build together a sustainable and inclusive future that is beautiful for our eyes, minds, and souls'[5]. The project Creating Actionable Futures (CrAFt), funded by the EU, focuses on supporting cities in their transition to climate neutrality through sustainable, inclusive, and visually appealing approaches[6]. By combining the principles of the New European Bauhaus and the EU Cities Mission, CrAFt serves as a bridge between these two initiatives.

The concept of smart cities, equipped with advanced technological and digital infrastructure, has emerged as a promising solution to the challenges posed by urbanisation and the rapid growth of city populations [6], [7]. This signals the vital role of digital technology in shaping the cities of tomorrow. Technological advances are expected to make significant contributions towards achieving the objectives outlined by the EU and UN for cities and nations. Furthermore, digital technology is set to play a crucial role in the outcomes of the CrAFt project, which specifically emphasises the development of smart cities and their integration into the project's endeavours.

Our previously conducted SLR [8] on digital support for climate-neutral, inclusive and beautiful cities indicated that to ensure that no one is left behind in the transition to climate neutrality, inclusive solutions should be designed. With our computer science background, the motivation is to design an inclusive, digital solution that can contribute to the involvement of citizens in a NEB-inspired way.

[2] https://sdgs.un.org/goals

[3] https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/horizon-europe_en

[4] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe_en

[5] https://new-european-bauhaus.europa.eu/index_en

[6] https://craft-cities.eu/

1.2 Project Description

This thesis presents a design and creation research strategy that culminates in the development of a mobile application prototype. Furthermore, it examines the impact of this solution on motivating citizens to change their environmental behavior. The features of the proposed application are based on the findings of an SLR [8], a focus group interview, and existing theories on motivation and individual behaviour change. The objective of the application is to use gamification and network aspects to motivate the citizens of a city to make positive changes in environmental behaviour, and the main application features include a feed, events, challenges, and interaction with other users.

1.3 Research Objective

The research objective of this project is to provide knowledge on how a digital platform should be designed to motivate citizens to positive environmental behaviour change by contributing to a more sustainable and inclusive city. The objective also includes investigating the use of gamification to make citizens change environmental behaviour. The research objective was decided based on the findings of an SLR [8] conducted in autumn 2022, leading up to this research project.

Based on these objectives, the following research questions were developed:

- RQ1: How should a digital platform be designed to motivate citizens to contribute to a sustainable and inclusive city?
- RQ2: Which specific gamification elements should be implemented in such a digital platform to make citizens change environmental behaviour?

1.4 Thesis Outline

The current section will outline the structure of this thesis. This introductory chapter introduces the thesis and the problem, outlining the motivation of the project, the project description, and the research objective. Chapter 2 explains the background of the study, highlighting important underlying initiatives, digital support, and related theories. Chapter 3 summarises the methodology and results of the SLR that led up to this thesis. The research methodology we followed is thoroughly explained in Chapter 4. The results of a focus group interview that was conducted to guide the development of the prototype are shown in Chapter 5, and the proposed mobile application solution is presented in Chapter 6. Chapter 7 presents the results of two iterations of evaluating the prototype through usability testing. The results, as well as other relevant parts of the project, are discussed in Chapter 8, and the project is concluded in Chapter 9.

Chapter 2

Background

The theoretical foundation of this project is rooted in a preliminary specialisation project conducted during the autumn semester of 2022. This project involved conducting an SLR on digital support for inclusive, climate-neutral, and beautiful cities, and this methodology and the most important results are presented in Chapter 3. This chapter will define and explain important concepts, problems, and initiatives that have led to and motivated our work. Section 2.1 explains the SDGs and outlines the most relevant goal for our project, Section 2.2 explains important initiatives supporting our work, Section 2.3 explains relevant digital tools used in this project, Section 2.4 explains the concept of smart sustainable cities, and Section 2.5 explains theories of behaviour change and the chosen models for our project.

2.1 Sustainable Development Goals

The general objective of our research, which led to the specific research questions and the objective of this research project, is to contribute to a more sustainable society. Therefore, the SDGs of the UN are important assets for our work. The brief definition of sustainable development often used, as proposed by the Brundtland Commission, is the 'ability to make development sustainable-to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs' [9, p. 10]. This definition can lead many people to focus only on equity across generations, abandoning the rarely cited, but important, environment and development parts of sustainable development[9]. The report also highlights the environmental part of sustainable development: 'The concept of sustainable development does imply limits -not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities.' [9, p. 11]. Several of the SDGs are related to this important aspect.

The UN *2030 Agenda for Sustainable Development* aims to lay out a shared roadmap for wealth and peace of the planet and its inhabitants today and into

the future. The 17 SDGs [5], an immediate appeal for action by all nations in an international partnership, are at the centre of the agenda. The SDGs pivot the five Ps as time-bound targets for sustainability: Prosperity, People, Planet, Peace and Partnership [10]. Each of the 17 goals also has 169 targets and 330 indicators attached to them [11], making them more measurable and tangible. The goals recognise that in order to end poverty and other deprivations, all countries must also work targeted to combat climate change, preserve our oceans and forests, enhance health and education, lessen inequality, and promote economic prosperity. The 17 SDGs build on the goal of "leaving no one behind" [1], meaning that the goals aim to include every person.

2.1.1 SDG 11 - Make Cities Inclusive, Safe, Resilient and Sustainable

Goal 11 of the SDGs is to make human settlements, communities, and cities safe, inclusive, sustainable, and resilient [5]. Since more than half of the world's population lives in cities and more than two-thirds are estimated to live in urban areas by 2050, good urban planning approaches are needed to make communities sustainable in the areas they occupy[2]. Cities are also contributing to more than 80% of the global GDP, highlighting why this goal is of great importance for the future of human beings. Cities around the world are also responsible for more than 70% of global greenhouse gas emissions, but urban development can be sustainable and generate inclusive prosperity if it is successfully planned and managed [5]. For all people to survive and prosper, new thinking is needed in urban planning to ensure safe, affordable, and resilient cities, providing green and inspiring living environments [5]. There are several targets connected to this goal with the aim of creating action to make cities sustainable. Some of them include "inclusive and sustainable urbanization", "provide access to safe and inclusive green and public spaces", "protect the world's cultural and natural heritage" and "reduce the environmental impact of cities". Our developed IT artefact aims to help meet this SDG, with the goal of influencing citizens' motivation to contribute more towards sustainable and inclusive cities or communities, as well as aiming to contribute to other initiatives.

2.2 Initiatives

Climate change and environmental degradation pose serious challenges to Europe and the world. Since the mid-twentieth century, the most significant driver of observed climate change has been greenhouse gas emissions from human activities[3]. With 70% of global greenhouse gas emissions coming from urban areas and an estimated increase in the amount of people living in urban areas from around half of the world's population today, to 7 out of 10 by 2050 [5], the emissions are also

[1] https://www.un.org/development/desa/disabilities/envision2030.html

[2] https://www.un.org/sustainabledevelopment/cities/

[3] https://www.epa.gov/climate-indicators/greenhouse-gases

expected to increase, due to increasing construction and transportation. This will, in turn, have a negative effect on climate change. With this in mind, several initiatives are working to reverse climate change and fulfil the SDGs, making sure that no one is left behind. This section will provide an overview of key concepts, goals, and projects that are currently supporting and motivating our research on sustainable and inclusive cities, and these initiatives have been important drivers when deciding on the research objectives for this thesis.

2.2.1 European Green Deal

As a set of policy initiatives by the European Comission, the European Green Deal[4] seeks to overcome the challenges of climate change and environmental degradation [2]. By adopting a set of proposals to make the EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels, the European Commission wants to ensure no net emissions of greenhouse gases by 2050. With this, they aim to be the first climate-neutral continent by 2050. Similarly to the SDGs, the European Green Deal wants to ensure that no one and no place is left behind in the path towards achieving climate neutrality.

2.2.2 New European Bauhaus

Sustainability, inclusivity, and aesthetics will be important, inseparable values in the cities of the future. The creative and interdisciplinary NEB[5] initiative encourages all Europeans to work together to create a more sustainable and inclusive future [12]. It connects the European Green Deal to our living spaces and experiences, being dubbed 'the soul which has led to an explosion of creativity across the European Union' by President of the European Commission, Ursula Von der Leyen. In connection to the European Green Deal, it focuses on helping European cities become climate neutral, as well as relating it to citizens' daily lives and emphasising inclusivity and beauty. The following bullet points describe the initiative[6]:

- 'It is a bridge between the world of science and technology, art and culture.
- It is about leveraging our green and digital challenges to transform our lives for the better.
- It is an invitation to address complex societal problems together through co-creation.'

[4] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[5] https://new-european-bauhaus.europa.eu/index_en

[6] https://new-european-bauhaus.europa.eu/about/about-initiative_en

2.2.3 Creating Actionable Futures

The CrAFt[7] project is a part of the EU's NEB initiative and seeks to place the transition to climate neutrality at the heart of stakeholders in urban areas[8]. In other words, the increase in urban quality and the reduction of greenhouse gas emissions is a matter that belongs to everyone [13]. By being an NEB initiative, the focus is on inclusiveness, aesthetics, and sustainability toward climate-neutral cities. To reach this target, three cities have been chosen to work as role models for other European cities, co-creating and testing a collaborative governance model for urban transformation. These cities are Amsterdam, Bologna, and Prague. The project will design and implement Climate City Contracts based on the experiences of these cities, and 60 other reference cities, highlighted in Figure 2.1. Both NEB and CrAFt use keywords such as sustainability, inclusiveness, and beauty. The next paragraphs will provide more insight into the relevant keywords for our project, their importance for the transition to climate neutrality, and how each of them is connected to our research objective.

Figure 2.1: CrAFt cities

[7] https://craft-cities.eu/
[8] https://craft-cities.eu/about-the-project/

Inclusion

The process of introducing people from marginalised groups into decision-making processes, activities, or positions of power [14, p. 15], with the purpose of ensuring that everyone has an equal opportunity to participate and have a positive experience, is called inclusion [15]. Recent research has shown that certain trends in society, such as an ageing population, more people with disabilities, increased diversity, and people becoming more isolated, are becoming more common in our society today [16]. These trends are being made worse by issues such as climate change [13]. Because of this, it is important that we find better ways to address these issues and ensure that everyone is included in the transition to climate neutrality. Our solution aims at being inclusive both when it comes to design and when it comes to the different activities that users can explore and contribute with, and will therefore help make the transition to climate neutrality an inclusive process.

For our research objectives, we have chosen to focus on how to design an inclusive digital solution for individual behaviour change, which can facilitate inclusion in cities. We believe that providing knowledge on how to design an inclusive digital platform to drive behaviour change is a suitable place to address inclusion in this project. However, other aspects of inclusion in cities, such as spatial justice in public open space (POS) [17], or ensuring affordable housing accessible to all, emphasising the creation of socially diverse neighbourhoods [18] in cities, could be a suitable fit for future research.

Sustainability

As defined by the UN's Brundtland Commission in 1987, sustainability is 'meeting the needs of the present without compromising the ability of future generations to meet their own needs' [19]. Practically, sustainability means creating a better quality of life for people today and in the future, while also preserving the planet and its resources for future generations. Sustainability will ensure that natural resources are used responsibly, helping to preserve the effects of climate change, and ensure that everyone has access to the resources they need to lead healthy lives, regardless of their background or circumstances. Reaching climate neutrality in a sustainable way is important to prevent the transition from occurring at the expense of future generations. This concept is strongly connected to our research objectives, as we aim to create a solution to make each user change environmental behaviour, hence living a more sustainable life. Our solution aims at motivating citizens to contribute to a sustainable city, by showing others their sustainable behaviours, thus help reach the urgent climate goals.

2.3 Digital Support

The use of digital technologies has grown massively in recent decades. The transition from analogue electronic and mechanical devices to current digital techno-

logies is referred to as the "digital revolution"[9]. This revolution started in the mid-1970s with the development of the personal computer [20] and is still ongoing. As digital technology plays a larger and larger role in our lives, people are also becoming more digitally literate, and they use digital tools in new areas and ways to improve and simplify their lives. By 2020 more than half of the world's population were Internet users, a number that is constantly increasing. Digital solutions are designed to make several aspects of people's lives easier, and users have also begun to take an active part in creating and improving solutions[10].

Digital technologies can help contribute to solving every single one of the 17 SDGs[11]. Some of the areas in which Information and Communication Technologies (ICT) can contribute are health, education, governance, economy, commerce, and agriculture. Digital technologies can also help reduce hunger and poverty, facilitate new jobs, reach climate neutrality, and make communities, urban areas, and cities more sustainable. To reach the 17 SDGs, there is an urgent need to include marginalised groups in the digital society. Those populations include women and girls, elderly people, people with disabilities, and indigenous people, groups that are often excluded from the growing digital society. As more people turned to the Internet amid lockdowns to continue working, studying, and staying in touch with friends and family, the COVID-19 pandemic has improved connectivity and the use of digital tools in general. This increase gives countries the opportunity to engage with their population in a more effective and digital way, to achieve the SDGs[12]. Some digital tools are more directly related to our research purpose than others and will be presented in the following sections.

2.3.1 Mobile Applications

A mobile application is a category of application software created specifically to run on mobile devices such as smartphones and tablets[13]. According to Islam, mobile applications are a piece of software that runs on a mobile device and performs specified tasks for users [21]. The apps provide isolated and limited functionality, and common examples are social media apps, games, browsing, and messaging. Technically, mobile applications differ from the software generally found on computers. The simplest forms of mobile applications use PC-based applications and designs to work on mobile devices as well. A native application is built specifically for iOS or Android and is downloaded from a specific application store. Most mobile applications are connected to the Internet, and there has been a drastic increase in mobile Internet use, with apps for almost everything in our daily life

[9] https://www.techopedia.com/definition/23371/digital-revolution

[10] https://courses.minnalearn.com/en/courses/digital-revolution/the-digital-revolution/what-is-the-digital-revolution/

[11] https://www.itu.int/en/mediacentre/backgrounders/Pages/icts-to-achieve-the-united-nations-sustainable-development-goals.aspx

[12] https://www.itu.int/en/mediacentre/backgrounders/Pages/icts-to-achieve-the-united-nations-sustainable-development-goals.aspx

[13] https://www.techopedia.com/definition/2953/mobile-application-mobile-app

[21]. Mobile applications are evolving rapidly [22], indicating that they will also be hugely influential in the future, also bearing in mind the rapidly increasing number of smartphone users in the world [23]. The concept of mobile applications is hugely relevant for this study, as the main part of the research involves this software.

Inclusive Design

Methodologies for creating products that comprehend and empower people from various backgrounds and abilities are referred to as inclusive design. It could cover topics including accessibility, age, financial position, location, language, race, and more [24]. By emphasising courteous communication and presenting content and functionality in ways that everyone can access and understand, an inclusive app puts people first[14]. Joyce explains the difference between "Inclusive design", "Accessibility", and "Universal design", concepts that are often mixed up [24]. Accessibility is about making sure solutions can be used by people with disabilities and therefore has a narrower scope than inclusive design, and standards such as the Web Content Accessibility (WCAG)[15] make accessibility easier to evaluate than universal and inclusive design. Universal design differs from inclusive design, as it aims to create *one* experience that can be accessed and used to the maximum extent by everyone, while inclusive design accepts a variety of design solutions as long as they meet the desired objective.

When designing inclusive applications, there are several important points to consider. According to Microsoft's inclusive design principles, exclusion occurs because we use our own biases for solving problems, and to design inclusively we must be able to recognise exclusion, learn from the diversity of people, and make solutions that can be used by everyone, including people with disabilities[16]. Apple Developer's design guidelines outline several points to consider to design inclusive mobile applications. These guidelines include using simple and intuitive designs, focusing on using plain and inclusive language, being approachable since it does not require people to have any particular knowledge to use the app, avoiding unnecessary references to specific genders, portraying human diversity, being accessible and avoiding stereotypes[17]. These aspects have all been considered when designing our mobile application prototype and should be considered also when moving forward, as we argue that our solution must be designed in an inclusive way to be able to foster inclusion in the community, thus leaving no one behind.

[14] https://developer.apple.com/design/human-interface-guidelines/inclusion

[15] https://www.w3.org/WAI/standards-guidelines/wcag/

[16] https://inclusive.microsoft.design/tools-and-activities/Inclusive101Guidebook.pdf

[17] https://developer.apple.com/design/human-interface-guidelines/inclusion

2.3.2 Gamification

The term gamification refers to the use of game design elements in non-game contexts [25, p. 9]. Although the principles of gamification existed before 2010, it was in that year the initial definition of gamification was proposed by Deterding *et al.* [25]. Gamification represents an approach to inspire, motivate, and change behaviour through gameplay or gameful experience, and could potentially increase engagement with climate change [26]. Dichev *et al.* have related gamification to the Fogg Behavior Model (FBM), which is presented in Section 2.5, stating that gamification can be a powerful tool to drive user activation above the threshold by motivating them, increasing their ability or perceived ability, and applying the right trigger at the right time [27]. In their examination of games and apps for sustainability, Douglas and Brauer also reached the conclusion that gamified apps have great potential as effective tools to promote sustainable behaviours, especially when compared to alternative methods of behaviour change [28].

Gamification should try to create game-like experiences in order to be effective [29], [30], and a classic way to implement game design elements into non-game context is to include Points, Badges and Leaderboards (PBL), widely used due to their effectiveness and implementability [31]. Other examples of game elements such as levels, storytelling, chance, goals, feedback, rewards, progress, challenge, avatar, and status are also used to harness motivation and provide a captivating UX [31].

Octalysis Framework for Gamification

The Octalysis framework[18], developed by Chou, is a gamification framework used to design gamified systems and evaluate applications in terms of their motivational drivers. As Figure 2.2 shows, the framework is designed as an octagon with eight motivational drivers for motivation, called core drives in the framework. Each side of the octagon represents a core drive that motivates toward certain activities and has individual characteristics and specifications. The octagon can be divided both horizontally and vertically to further group core drives with similar attributes. By dividing it vertically, the cores on the right represent creativity, while the cores on the left represent logical thinking. The core drives on the left are extrinsic motivators, the motivation comes from the desire to obtain something, such as a goal or a good. The core drives to the right are intrinsic motivators, as the activity itself is rewarding. By horizontally dividing the octagon, the top half represents white-hat gamification cores, which utilise positive techniques to drive users to interact with the application, while the bottom half represents black-hat gamification cores, which use negative means to urge users to engage with the application.

The use of the Octalysis framework is supported by Morschheuser *et al.* stating that it has a good reputation among gamification practitioners because it bridges

[18] `https://yukaichou.com/gamification-examples/octalysis-complete-gamification-framework/`

psychology and game elements [32], [33]. Karać and Stabauer also mention that the framework has been employed in a variety of research contexts, making it an appropriate gamification framework for our research [34]. The framework will be used in the creation, ideation and justification of our system, as is the most common practice with the use of this framework [33]. The implemented core drives in our application are *1: Epic Meaning & Calling*, *2: Development & Accomplishment* and *5: Social influence and relatedness*. By implementing these core drives, we do not rely on black-hat core drives, ensuring that users maintain a sense of control and minimise the risk of users developing unhealthy obsessions or even addiction, which can occur when utilising black-hat gamification techniques. Additionally, by not employing any black-hat techniques, we reduce the risk of users dropping out of the system because they do not feel good about their actions[19]. The choices of core drives are also based on the desire to implement both left side and right side core drives, to exploit both intrinsic and extrinsic motivators, thus ensuring that the activities themselves are rewarding to make users continuously engaging in the activities[20].

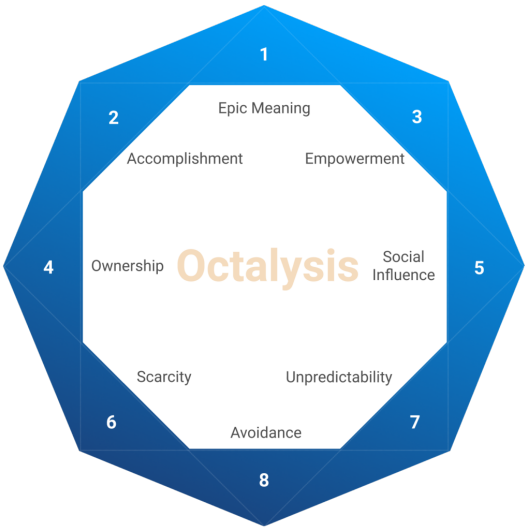

Figure 2.2: Core Drives in the Octalysis framework [35]

2.4 Smart Sustainable Cities

Digital tools will play an important role in achieving climate neutrality in cities. Several definitions have been made on what makes a city smart. According to Woetzel *et al.* a city is smart if digital technologies and data are used to improve decision-making and improve the quality of life of the inhabitants [36]. Magalhães *et al.* outline several definitions, where one of the most precise states that a smart

[19] https://yukaichou.com/gamification-study/white-hat-black-hat-gamification-octalysis-framework/
[20] https://yukaichou.com/gamification-examples/octalysis-complete-gamification-framework/

city uses ICT to make living in the city more interactive, accessible, and efficient [37]. Therefore, this definition also includes the important aspect of the inclusion of citizens in smart cities.

The concept of smart sustainable cities has manifested itself in recent years [38], and the concept has been recognised as a potential solution to the previously mentioned climate challenges in cities and human settlements. Earlier references have separated smart cities and sustainable cities, but there has been a lack of connection between those two concepts. Bibri and Krogstie state that, based on the already massively widespread and used urban ICT solutions, ICT also has taken an important role in the debate on sustainability in urban areas [38]. However, they claim that there is a problem of smart solutions in cities not making contributions to sustainability, and sustainable city solutions are not being smart. Focus must therefore be on connecting those two types of solutions and making cities both smart and sustainable. Höjer and Wangel [39] have developed a definition of a Smart Sustainable City, as shown in Figure 2.3.

A Smart Sustainable City is a city that

- meets the needs of its present inhabitants
- without compromising the ability for other people or future generations to meet their needs, and thus, does not exceed local or planetary environmental limitations, and
- where this is supported by ICT.

Figure 2.3: Definition of Smart Sustainable Cities from [39]

NTNU has a knowledge cluster named "NTNU Smart Sustainable Cities". It consists of people from a broad range of professional fields, such as architects, designers, artists, engineers, ICT specialists, and people from social and economic sciences. They describe their work and research for smart and sustainable cities of the future as follows: 'Together, we offer open urban innovation, co-creation and decision support for people-centric smart sustainable cities, supporting public and private sector as well as civic society with a unique merger of transformative, technological, artistic and practice-based research. With urban living labs, public-private partnerships and integrated design thinking, the initiative supports cities in their ambition to truly become cities for people, cities of culture, green cities, digital cities and learning cities – in short, truly smart and sustainable.'[21] This work is also connected to the aforementioned NEB initiative and the CrAFt project, and therefore connected to our research objective.

[21] https://www.ntnu.edu/smartcities

2.5 Behaviour Change

In addition to being a computer science research project, our research objective also concerns a psychological aspect, as we try to connect the design of a digital platform to human motivation and behaviour change to help cities become more sustainable and inclusive. Human behaviour and motivation are enormously compound and possibly overwhelming areas of research, for instance, having in mind the huge variety of internal and external factors that can influence the decision-making process when individuals perform an act [40]. However, Heimlich outlines that 'To change behaviors, we must consider each of the individual behaviors and actions that add up to the larger environmental behavior we encourage people to undertake. In dissecting behaviors into habits, tasks and skills, opportunities exist for changing the larger behaviors' [40, p. 218]. Through several decades of studies on different techniques for behaviour change, a number of different models have been developed to guide academics and practitioners in their work and research [40]. Therefore, we decided to use two such models to help connect the behavioural aspect to our digital solution. When deciding what specific models to use for this project, we focused on behaviour change models for individuals that seem fairly easy to grasp, also applicable to our objective.

2.5.1 Conscious Techniques

Pinder outlines rational-action behaviour models as the ones often cited and used when technology is used to drive behaviour change [41]. These are known as conscious behaviour change models, which imply that the behaviour is driven by conscious mechanisms. These models or techniques usually involve conveying a convincing message that includes spoken or numeric details to encourage individuals to recognise the importance or outcomes of performing a specific behaviour. As a result, this encourages people to develop intentions to modify their behaviour, and historically, these information-based interventions have been the main focus in the change of health-related behaviour [42]. These techniques might also be used to impart the necessary abilities for behavioural change.

Based on our research objective, there exists a variety of such theoretical models that can be applied to our specific purpose. The article by Petersen *et al.* [43] describes "Smiling Earth", a mobile application designed to increase citizens' awareness of their own carbon footprint, by informing them with data from their daily activities with the goal of motivating citizens to change their behaviour to reduce CO2 emissions. In the paper by Petersen *et al.*, the Transtheoretical Model (TTM) is adopted as a conceptual framework to support behaviour change through the mobile application. Cellina *et al.* has anchored the persuasive application *GoEco!* in the same model, also presenting a table of features and components of the application specifically designed to help individuals overcome each of the stages in the model. The TTM is a model of intentional change, which is based on the decision-making of the individual who wants to make a change [44].

Sugarman and Lank outline that eco-feedback design needs to be directed at the individual user, as they are at different stages and positions [45]. The important aspect of this model is the recognition that individuals go through several stages in changing their behaviour. Many environmental educators often fail by omitting the steps required to reach a target outcome and instead focus on the outcome of the behaviour [40]. The TTM seems like an appropriate model for the support of individual behaviour change based on our research objective, as we want to motivate citizens to change environmental behaviour. As we are developing a mobile application prototype, the ability to connect specific design features of the application directly to stages of behaviour seems like a structured way to make sure that the application design meets the overall objective. There are, however, several limitations of the TTM, which should be considered when using the model. LaMorte outlines that the model ignores social context, such as, for example, income of individuals, there are no set criteria to decide a person's stage of change, there is no clear knowledge of how much time is needed at each stage, and there is also an assumption that people make logical choices in their decision-making progress [46].

The TTM describes six stages an individual must go through in order to change behaviour [46]:

1. Precontemplation: The individual does not intend to make a change in behaviour, and this is often due to unawareness of the negative consequences of their behaviour.
2. Contemplation: The individual intends to start better behaviour within the next 6 months, and they recognise that their behaviour may have problematic consequences. At this stage, the individual may still have ambivalent feelings towards the behaviour change.
3. Preparation (Determination): The individual is ready to take action in the near future (within 30 days), and believes that changing their behaviour is for the better
4. Action: The individual has recently changed behaviour and intends to continue with the new behaviour.
5. Maintenance: The individual has sustained the behaviour for a longer period (more than 6 months) and intends to continue with the behaviour change
6. Termination: The individual does not wish to return to the old behaviour and is sure to succeed with the behaviour change.

Ten processes of change are also highlighted, to assist individuals in achieving and sustaining behaviour change, and to understand *how* shifts in behaviour occur [46]:

1. 'Consciousness Raising - Increasing awareness about the healthy behavior.
2. Dramatic Relief - Emotional arousal about the health behavior, whether positive or negative arousal.
3. Self-Reevaluation - Self reappraisal to realize the healthy behavior is part of who they want to be.

4. Environmental Reevaluation - Social reappraisal to realize how their unhealthy behavior affects others.
5. Social Liberation - Environmental opportunities that exist to show society is supportive of the healthy behavior.
6. Self-Liberation - Commitment to change behavior based on the belief that achievement of the healthy behavior is possible.
7. Helping Relationships - Finding supportive relationships that encourage the desired change.
8. Counter-Conditioning - Substituting healthy behaviors and thoughts for unhealthy behaviors and thoughts.
9. Reinforcement Management - Rewarding the positive behavior and reducing the rewards that come from negative behavior.
10. Stimulus Control - Re-engineering the environment to have reminders and cues that support and encourage the healthy behavior and remove those that encourage the unhealthy behavior.'

Fogg [47] presents a different model for understanding human behaviour. The FBM focuses on three factors that lead to behaviour: motivation, ability, and triggers. Therefore, to perform a behaviour, the individual must have sufficient motivation for the behaviour, have the required skills to perform the behaviour, and be triggered to perform the behaviour, and all these three factors must occur at the same time [47]. The FBM is especially applicable in the analysis and design of persuasive systems. The model outlines several subcomponents for each of the three factors.

The following core motivation elements are highlighted in the model by Fogg [47]:

1. *Pleasure / Pain* - people respond to what happens in the moment, causing an immediate result of the action
2. *Hope / Fear* - based on the expected outcome of an action
3. *Social acceptance / rejection* - based on actions to win social acceptance, or avoid rejection

The following six elements of simplicity (ability) are highlighted:

1. *Time* - If a behaviour requires time, it might not be simple, as people might not have the time available
2. *Money* - If a behaviour costs money, it might not be simple, especially for people with limited financial resources
3. *Physical Effort* - If a behaviour requires physical effort it might not be simple
4. *Brain Cycles* - If a behaviour requires hard thinking, it might not be simple
5. *Social Deviance* - If a behaviour requires breaking the social rules and norms of society, it might not be simple
6. *Non-Routine* - If a behaviour is out of routine, it might not be simple

Finally, the following three types of triggers are highlighted:

1. *Spark* - Applied when a person lacks the motivation to perform a behaviour

2. *Facilitator* - Applied when a person lacks the ability to perform a behaviour
3. *Signal* - Applied when a person has both motivation and ability to perform a behaviour, acting as a reminder

Rist highlights that this model has been used in a variety of different fields [48], and applies the model to the change in behaviour related to energy savings. Furthermore, Rist justifies the use of the FBM with simplicity and because of over 20 years of experience from studies in several different areas, making it a flexible model. Simplicity and flexibility also seem to make the FBM a good fit for our research project, as we have a limited time window and little experience with behaviour change models. Sugarman and Lank outline that most of the work in Human-Computer Interaction (HCI) using the TTM focuses only on motivation, while the FBM offers a broader view by also considering how technology can increase ability and also trigger users [45]. Sugarman and Lank also present a number of different behaviour modification theories, arguing that those theories are incorporated into the FBM, and can be mapped onto the different dimensions of the FBM. Therefore, the FBM seems to cover a lot of important behavioural theory, even though it is a fairly simple model, also providing additional dimensions that the TTM does not.

The TTM and the FBM will be used as behaviour change models in this project. Specifically, they will be used in our planning, conduction, and evaluation of the developed mobile application prototype to connect the design elements to different stages of behaviour change and different drivers of motivation. The models will help justify the different features included in the application and also provide a tool to help evaluate and discuss the findings from a behavioural change perspective. Therefore, the inclusion of these models will be very important for this project, and the aspect of behavioural change will also be an important part of the progress in this area of research.

2.5.2 Nonconscious Techniques

As an alternative to conscious, rational-action models, Pinder claims that there has been an increased interest in nonconscious behaviour techniques such as Cognitive Bias Modification (CBM) [41]. Although the use of these kinds of models has shown promise, they have not yet been implemented or evaluated on smartphones. CBM is, as defined by MacLeod, 'direct manipulation of a target cognitive bias, by extended exposure to task contingencies that favour predetermined patterns of processing selectivity' [49, p. 191]. These techniques aim to directly alter automatic cognitive functions including interpretation and attention [50], and there has recently been increased interest in using such a model to drive individual behaviour change [41]. Pinder presents a research project investigating the most effective smartphone gestures to accept and reject stimuli for healthy eating and finds proof that smartphone CBM could change some measures of eating attitudes, however, the area needs more research. There is also empirical evidence suggesting that rational approaches based on information have a tendency to fail

in the long term, but are either way commonly used to drive technology-based behaviour change.

We have chosen not to apply a CBM technique in this project. CBM is a fairly complex model that seems harder to understand and apply correctly than the TTM and the FBM. As we are inexperienced in the field of psychology and behaviour change, and due to time limitations, we rather decided to use simpler models, which to our knowledge have been used more for similar purposes. With our research goals in mind, we argue that the TTM and the FBM are more directly applicable, as these models give us the ability to connect different design choices to specific steps and elements, and we can therefore easier justify and evaluate our design. However, Pinder highlights some interesting results about the use of CBM, and further research on the field will help to explore the area more and provide more empirical evidence.

Chapter 3

Systematic Literature Review

Prior to this project, we conducted an SLR [8]. This literature review was done as part of the course TDT4501 - Specialization Project, with the project description available in Appendix A. The objective of the literature review was to build a foundation of knowledge about currently existing digital technologies contributing to climate-neutral, inclusive, and beautiful cities, and to identify research gaps connected to this, with the intention of using this knowledge to create a digital solution in the spring semester. More specifically, we wanted to investigate what types of digital tools are the most commonly used, what specific city challenges are mostly addressed, and how the digital tools specifically contribute to solving these challenges. After performing a structured data collection methodology, we ended up considering a total of 16 primary studies in the SLR.

3.1 Research Methodology

The methodological framework for our SLR was provided by Kitchenham [51], following the main phases of this framework, namely *planning the review*, *conducting the review*, and *reporting the review*. The first two phases will be presented in this chapter, while the third phase consisted of us being co-authors on the paper *Towards understanding digital tools contributing to climate neutral, inclusive, and beautiful cities - A systematic literature review* [1], that was accepted and presented at the ICSE[1] GREENS[2] 2023 - an international workshop on green and sustainable software. A systematic literature review is a method to find, analyse and interpret all the research that is currently done on a certain topic or research area, making it a good choice considering the objective of our project. Primary studies refer to individual studies included in a systematic review. In contrast, a systematic review itself is considered a secondary study, as it involves the analysis and synthesis of multiple primary studies [51].

[1] https://conf.researchr.org/home/icse-2023

[2] https://greensworkshop.github.io/GREENS2023/

3.1.1 Research Questions

According to Kitchenham [51], the formulation of research questions is the key component of the planning stage. Based on the objectives of the SLR, namely to investigate and provide knowledge on the current status of digital support for climate-neutral, inclusive, and beautiful cities, three research questions were formulated. These research questions are shown in Table 3.1 and are followed by an explanation of why these questions were important for our work.

Research question	Motivation
RQ1: What are the most common types of digital support contributing to climate-neutral, inclusive and beautiful cities?	Get insights into what kind of digital support is best suited to tackle the challenges of climate neutrality, inclusion and beauty.
RQ2: What are the city challenges these digital solutions aim to solve?	Which challenges are key to deal with to achieve beautiful, climate neutral and inclusive cities?
RQ3: How are these digital solutions contributing to either climate-neutral, inclusive or beautiful cities?	Get insights into how the technology can be used to tackle the challenges, to be used as inspiration for further research.

Table 3.1: Research questions from SLR autumn 2022 [8]

3.1.2 Data Collection

The Scopus[3] database was chosen to perform the search for studies since it can handle complex search strings and contains sources from a wide range of fields. According to Kitchenham, the first phase of defining a search string consists of identifying search terms. The title of the thesis was used as a basis for the identification of terms, resulting in *Digital support*, *Inclusive*, *Beautiful* and *Climate neutral* as the primary terms for the database search. Several alternative terms were also explored and are shown in Table 3.2.

The search string, which can be seen in Table 3.3, was generated using the previously identified primary and alternative terms. The search only included papers from the last 5 years, as Bibri and Krogstie's review on smart sustainable cities from 2017 was used as a starting point for the review [52], and we wanted to investigate what progress had been made on the field after this review was conducted. As our field of study is computer science, we chose only to include papers from this research area.

[3] `https://www.scopus.com/`

digital	**sustainable**	**climate**	**inclusive**	**beautiful**	**city**
digital support	sustainability	climate neutral	inclusion	enriching	cities
digital tools	renewable	-	-	appealing	urban
software	green	-	-	wonderful	urban area
digitali?ation	livable	-	-	magnificent	municipal
digiti?ation	supportable	-	-	stunning	-

Table 3.2: Table of terms from SLR autumm 2022 [8]

Database	**Search string**	**Results**
Scopus	(("digital*" OR "digital support" OR "digital tools" OR "software" OR "digitali?ation" OR "digiti?ation" OR "app") AND ("sustainable" OR "sustainability" OR "climate" OR "climate neutral" OR "inclusive" OR "inclusion" OR "enriching" OR "beautiful") AND ("city" OR "cities"))	1280

Table 3.3: Search query from SLR autumn 2022 [8]

3.1.3 Inclusion and Exclusion Criteria

The search string yielded 1280 results in Scopus. Table 3.4 shows the inclusion criteria and Table 3.5 shows the exclusion criteria applied to the obtained papers.

Number	**Inclusion criteria**
1	Papers that clearly present in either title or abstract the use of digital support aiming to contribute to either inclusion, climate neutrality or beautiful cities
2	Papers not specifically aiming at contributing to inclusion, climate neutrality or beautiful cities, but nevertheless clearly present some digital support that could contribute to this initiative

Table 3.4: Inclusion criteria from SLR autumn 2022 [8]

After applying the inclusion and exclusion criteria to filter out papers based on title, the remaining set of primary studies for abstract reading was 211. These papers were subject to a measurement approach for us to agree on which papers to include and exclude based on the contents of the abstract. We chose to use a simple scoring system, where we read all abstracts and scored each of them from 0-2 independently, with the aforementioned criteria as a guideline. Table 3.6 shows a small sample of the table we used to determine whether to include or exclude each paper based on scores. If we definitely wanted to exclude a paper it was given a score of 0, if we were unsure whether to include it or not, it was given a score of 1, and if we definitely wanted to include the paper, it was given a score

Number	Exclusion criteria
1	Papers not written in English
2	Papers with typographical errors in the title
3	Papers not associated with the field of Computer Science
4	Papers not accessible without having to pay
5	Papers without author(s)
6	Papers without abstract
7	Papers with insufficient details in the title
8	Papers from 2017 or older

Table 3.5: Exclusion criteria from SLR autumn 2022 [8]

of 2. All papers achieving a total score of 4 were included, and all papers with a score of 0 and 1 were excluded. The papers with a total score of 2 and 3 were discussed in order to make a final decision. After this phase, 54 primary studies remained for quality assessment.

Study	Score Ferdinand	Score Eivind	Include?
Briseno, R. A., *et al.*, 2020	2	2	Yes
Bonora, L., *et al.* , 2019	1	2	Yes (after discussion)
Ahmed, I., *et al.* , 2022	1	1	No (after discussion)
Choudhary, P. and P. Sarthy, 2022	1	0	No
Zheng, L., *et al.*, 2019	0	0	No

Table 3.6: Sample of agreement table from SLR autumn 2022 [8]

3.2 Quality Assessment

When conducting a quality assessment of the remaining primary studies, we considered three main quality criteria, as done by Papavlasopoulou, Giannakos and Jaccheri [53], and also by Dybå and Dingsøyr [54]. Table 3.7 shows the three quality criteria in which the answer had to be yes for all three questions, in order for the primary studies to be included. After applying all quality criteria to the remaining papers, the final set of primary studies was 16.

Number	Quality criteria
1	Is the paper based on empirical research?
2	Are the aims and objectives of the paper clearly reported?
3	Is there an adequate description of the context in which the research was carried out?

Table 3.7: Quality criteria from SLR autumn 2022 [8]

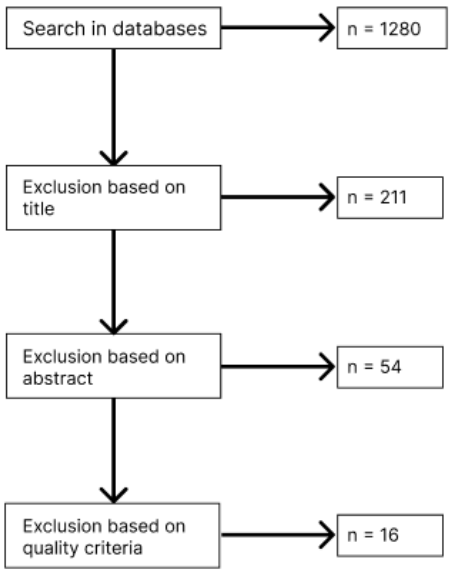

Figure 3.1: Study selection

3.3 Data Analysis

The 16 primary papers were analysed based on the data analysis method used by Papavlasopoulou, Giannakos and Jaccheri [53], and also by Dybå and Dingsøyr [54]. To best answer the research questions, the 16 papers were thoroughly analysed based on the following parameters, also outlined what specific information has been extracted for each parameter:

- **Location of study** - Country
- **Digital tools**
- **Areas of interest** - Climate-neutrality/inclusion/beauty
- **Contribution** - How the digital tools contribute to the area(s) of interest
- **Type of methodology** - Qualitative/quantitative/mixed

- **Research methodology**
- **Journal/conference**

3.4 Results

The following subsections will summarise the findings of the data analysis part of the SLR [8] carried out on our 16 primary studies. Both general results and results specifically related to the research questions are presented.

3.4.1 General Findings

As shown in Table 3.5, all primary studies included are from 2018 or later. Figure 3.2 shows the distribution of years with 4 studies from 2019, 3 from 2020, 6 from 2021 and 3 from 2022. 9 of the 16 papers are from the last two years, 2021 and 2022.

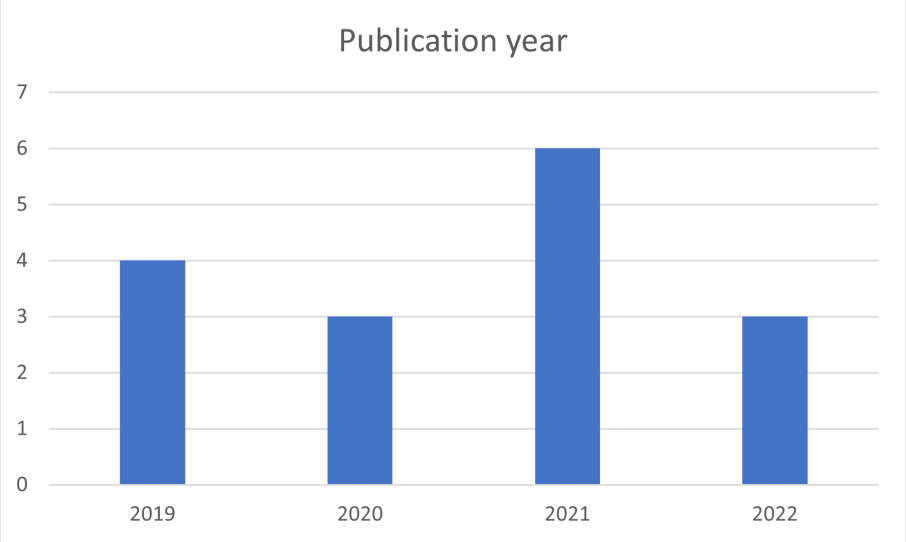

Figure 3.2: Publication year from SLR autumn 2022 [8]

The distribution of the locations where the research studies were carried out is shown in Figure 3.3. This figure is a world map depicting countries with two studies as blue and one study as orange. There were 14 different locations identified in the 16 primary studies, explained by one paper doing research on two different locations and one study performing a case study among two locations.

3.4.2 Research Methodology

The 16 primary studies have an almost even distribution of qualitative and quantitative research methodologies. Seven papers have used a qualitative approach,

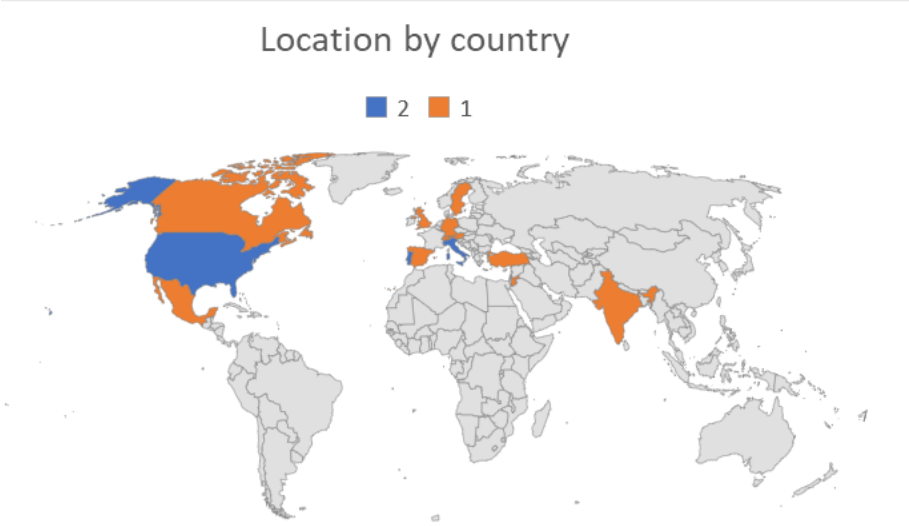

Figure 3.3: Location map from SLR autumn 2022 [8]

while six have used a quantitative one. The three remaining have used a mixed approach. The distribution is shown in Figure 3.4.

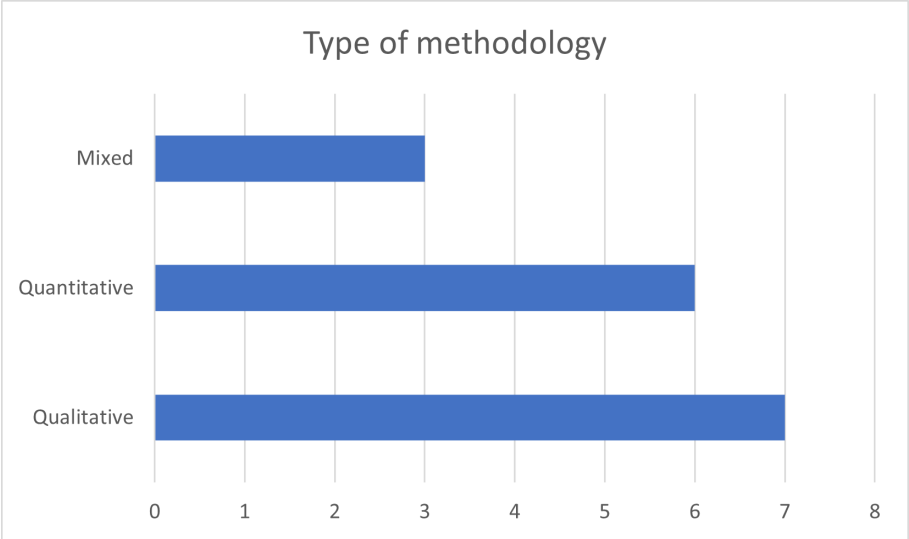

Figure 3.4: Type of methodology from SLR autumn 2022 [8]

The obtained primary studies use several different research methodologies and data generation techniques, as shown in Figure 3.5. Some of the papers have used a mixed approach with both quantitative and qualitative methods, and one paper has combined two qualitative methods, resulting in a total number of research methodologies being higher than the number of papers. Survey is the most used research strategy, and most of these studies use a kind of questionnaire for

data generation. Observation has been used as a data generation method by five of the primary studies, four have been using interviews for data generation, three have been using case study as research strategy and one primary study has used "Research Through Design" [55].

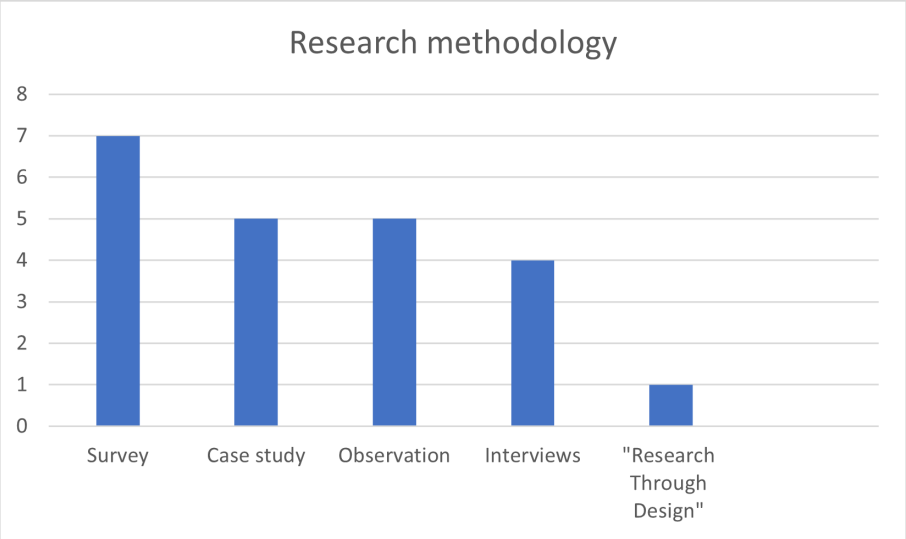

Figure 3.5: Research methodology from SLR autumn 2022 [8]

3.4.3 Digital Tools

Figure 3.6 and Table 3.8 show the distribution of digital tools used in the primary studies, and as shown in the figures, mobile application is the dominant technology. The second most used technology is both Internet of Things (IoT) and Artificial Intelligence (AI).

3.4.4 City Challenges

Table 3.9 shows the specific city challenge each of the primary studies assesses, and the distribution is shown in Figure 3.7. As seen in Figure 3.7 most of the papers regards either climate neutrality or inclusion, but only one paper regards more than one challenge. The specific contributions are explained in Table 3.10.

3.4.5 Contributions

Although the approaches to addressing the aforementioned city problems vary, they all suggest digital solutions that can help create climate-neutral, inclusive, or beautiful cities. Table 3.10 explains each digital contribution from the primary studies.

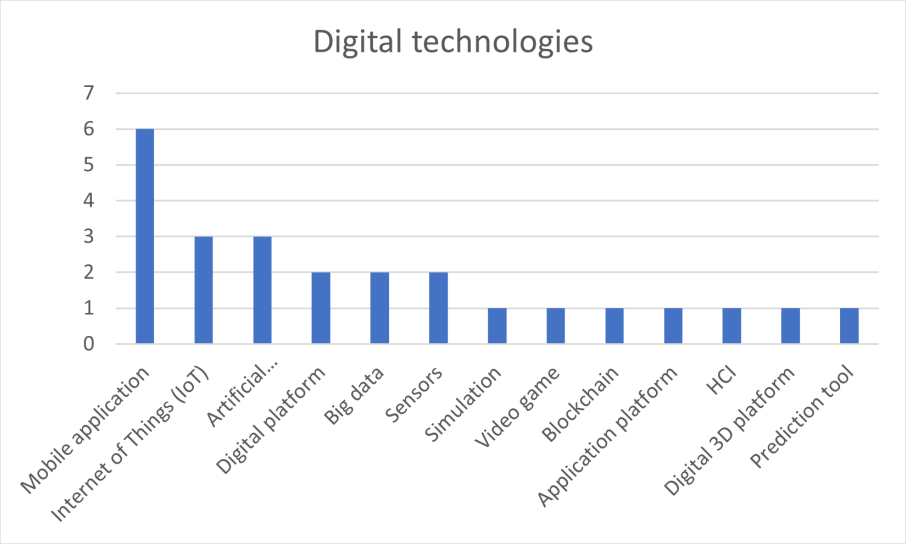

Figure 3.6: Digital technologies from SLR autumn 2022 [8]

3.5 Conclusion

The SLR findings outline some interesting results. There seems to be an increasing number of papers on digital support for climate neutral, inclusive or beautiful cities, with an increase of almost 30% from 2019/20 to 2021/22, and a clear majority of the papers present European research.

The results regarding the research questions show some clear trends. Although the primary studies show proof of many well-functioning digital technologies for solving the focus challenges, mobile application is the most used technology, as shown in Figure 3.6. Some of these papers have developed a mobile application to solve a problem, and some have proposed a mobile application as the most suitable digital technology for a specific issue. Gamification and nudging also seems to be positive when it comes to citizen participation in smart cities.

Among the issues of climate neutrality, inclusion, and beauty in cities, most of the papers focus on solving some climate neutrality issues, indicating that this has been the most addressed issue in recent years. Fewer papers addressed inclusion issues, and even fewer papers focused on beauty. Although we found papers regarding all of these focus areas, none of our included papers presents solutions regarding the intersection between climate-neutral, inclusive, and beautiful cities. With the object of our project in mind, there seems to be a need for such a digital solution to be further investigated.

The contributions provided by the different primary studies differ, but an interesting finding is that citizen participation is proven to help cities change. Crowdsourcing, citizen behaviour modification, and participation of citizens all seem to have an effect on reaching the future goal of climate-neutral, inclusive, and beautiful cities. Specific elements such as gamification, nudging, and facilitation

Study	**Digital technologies**
Briseño, R. A., *et al.*, 2020 [56]	Digital platform/Simulation
Rinaldi, A. and K. Kianfar, 2021 [57]	App
Bonora, L., *et al.*, 2019 [58]	Video game
Boulanger, S. O. M., *et al.*, 2020 [59]	Big data/Sensors
Magalhães, M., *et al.*, 2021 [37]	Mobile application
Varghese, C., *et al.*, 2021 [60]	Mobile application/AI/IoT/HCI
Baghezza, R., *et al.*, 2022 [61]	Machine learning/IoT/Sensors
Bibri, S. E. and J. Krogstie, 2020 [38]	Big data/IoT
Trillo, C., *et al.*, 2021 [62]	Digital 3D model
Melanie Piser, M. A., *et al.*, 2019 [63]	Digital platform
Varde, A. S., *et al.*, 2022 [64]	Machine learning/Prediction tool
Ferron, M., *et al.*, 2019 [65]	Mobile application
Ertz, O., *et al.*, 2021 [66]	Application framework
Luger-Bazinger, C. and V. Hornung-Prähauser, 2021 [67]	Mobile application
Rodrigues, J. and A. Cardoso, 2019 [68]	Blockchain
Remelhe, E., *et al.*, 2022 [69]	Mobile application

Table 3.8: Digital technologies from SLR autumn 2022 [8]

through mobile applications or platforms also show positive contributions. Using digital tools to provide insight upon which decision- and rule-makers can act, are also proven to contribute positively to the initiative.

In summary, the SLR provided a lot of insight into what digital technologies and city challenges that are addressed today and what areas that should be focused on in the coming years. These insights have guided this research project.

3.5.1 Further Work

To meet the objective of this research project, an application will be developed with the research gap discovered from the SLR as a starting point. With the lack of focus on, and digital tools for climate-neutral, inclusive, and beautiful cities,

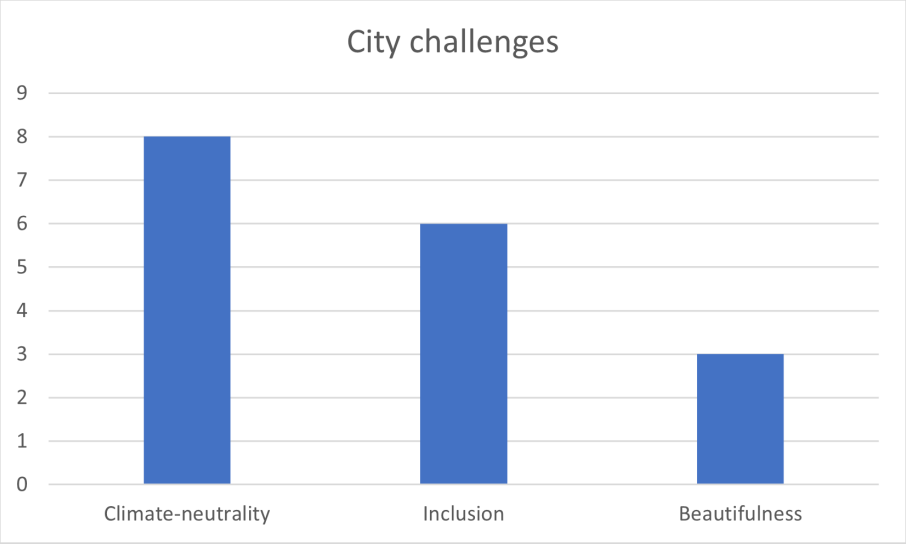

Figure 3.7: City challenges from SLR autumn 2022 [8]

further research into this topic will be conducted. Through further research on this topic, we want to end up with a digital tool, specifically a mobile application, to help citizens change their behaviour and, in turn, better contribute, to a more climate-neutral, inclusive, and beautiful city. This digital tool should raise awareness of the problem and also provide information to citizens on how best to contribute. The Figma web design tool[4] will be used for prototyping, as we have good experience with using this from previous projects, and it allows prototypes to be interactive and easily testable through the use of usability testing.

For the development of the digital tool, a design and creation research strategy will be followed. With this being an iterative process, we are seeking to learn as we develop the digital tool. In the initial stages of development, we will conduct a focus group interview to guide the design of the digital solution and provide insight into the motivational aspects of actively contributing in a city. We will also perform usability testing of the mobile application prototype and make improvements based on these tests, making it an iterative design cycle. The following chapters will go into more detail about the methodology followed and the proposed mobile application prototype.

[4]https://www.figma.com/

Study	**City challenges**
Briseño, R. A., *et al.*, 2020 [56]	Climate neutrality - traffic reduction, reduce CO_2 footprint
Rinaldi, A. and K. Kianfar, 2021 [57]	Inclusion - dialogue and communication between cultures
Bonora, L., *et al.*, 2019 [58]	Climate neutrality - educational
Boulanger, S. O. M., *et al.*, 2020 [59]	Beauty - cultural heritage in urban environments
Magalhães, M., *et al.*, 2021 [37]	Inclusion - citizen participation
Varghese, C., *et al.*, 2021 [60]	Climate neutrality - sustainability, reduce food waste
Baghezza, R., *et al.*, 2022 [61]	Inclusion - Evaluation of accessibility and inclusion
Bibri, S. E. and J. Krogstie, 2020 [38]	Climate neutrality - solutions to reduce pollution, use energy effectively and for urban metabolism
Trillo, C., *et al.*, 2021 [62]	Beauty - heritage conservation
Melanie Piser, M. A., *et al.*, 2019 [63]	Inclusion - citizen participation
Varde, A. S., *et al.*, 2022 [64]	Climate neutrality/beauty - air pollution, cleaner air
Ferron, M., *et al.*, 2019 [65]	Climate neutrality - mobility change
Ertz, O., *et al.*, 2021 [66]	Inclusion - senior citizens
Luger-Bazinger, C. and V. Hornung-Prähauser, 2021 [67]	Climate neutrality - sustainable mobility
Rodrigues, J. and A. Cardoso, 2019 [68]	Inclusion - people with disabilities
Remelhe, E., *et al.*, 2022 [69]	Climate neutrality - traffic reduction, reduce CO_2 footprint

Table 3.9: City challenges from SLR autumn 2022 [8]

Study	**Digital contributions**
Briseño, R. A., *et al.*, 2020 [56]	Simulation to plot situations to switch a percent of the citizens that use the bus units, train or particular vehicles and commuting to the bicycle mobility in Guadalajara.
Rinaldi, A. and K. Kianfar, 2021 [57]	Mobile application fostering dialogue and communication between citizens from different cultures.
Bonora, L., *et al.*, 2019 [58]	Game for communication and teaching of traditional topics of environmental sciences, to make young students into involved and aware citizens.
Boulanger, S. O. M., *et al.*, 2020 [59]	Provides knowledge into how sensors and big data analysis can be used in the transformation of valuable cultural heritage urban environments.
Magalhães, M., *et al.*, 2021 [37]	Provides understanding of the best digital approach to involve citizens to participate to a more sustainable city, and to meet citizens' needs.
Varghese, C., *et al.*, 2021 [60]	Assists food donation to reduce food waste.
Baghezza, R., *et al.*, 2022 [61]	Evaluates accessibility and inclusivity in smart cities.
Bibri, S. E. and J. Krogstie, 2020 [38]	Case study resulting in showing the main data-driven smart solutions for improving and advancing environmental sustainability in cities, with the solutions being smart meters, smart buildings, smart environmental monitoring and smart urban metabolism.
Trillo, C., *et al.*, 2021 [62]	Raises awareness in the cultural value of tangible and intangible heritage.
Melanie Piser, M. A., *et al.*, 2019 [63]	Digital platform for digital citizen participation, making the citizen able to participate in urban development, reduction of resources and protection of environment and nature.
Varde, A. S., *et al.*, 2022 [64]	Predicts fine particle pollutants and air quality. These predictions can be used by lawmakers and citizens to contribute to better air quality.
Ferron, M., *et al.*, 2019 [65]	Promotion of a positive behavioral change of mobility habits, by encouraging citizens to choose other types of transportation than car.
Ertz, O., *et al.*, 2021 [66]	App that makes it easier for senior citizens to walk around the city.
Luger-Bazinger, C. and V. Hornung-Prähauser, 2021 [67]	App that encourages citizens both to choose sustainable ways of transportation and to seek out sustainable initiatives around the city.
Rodrigues, J. and A. Cardoso, 2019 [68]	Blockchain for better inclusion of People with Disabilities (PwD).
Remelhe, E., *et al.*, 2022 [69]	Lowering the time used to find a parking space, also reducing the amount of CO2 produced by vehicles.

Table 3.10: Digital contributions from SLR autumn 2022 [8]

Chapter 4

Research Methodology

This chapter presents the research methodology followed in this research project. This chapter will thoroughly explain the research methodology chosen, mainly following the research principles presented by Oates [4]. The research strategy chosen for this project is design and creation, and the data generation methods are a focus group interview, usability testing, observation, and a questionnaire, namely the SUS. The research strategy and the data generation methods, and the rationale for using each of them, will be explained in detail in this chapter. The research questions of this project are presented in Section 4.1, and Section 4.2 explains the design and creation research approach chosen for this project, including the data generation techniques. The chosen data analysis methodology is presented in Section 4.3.

To ensure ethical conduct of this research project, various considerations were addressed. Participants' rights, including the right to refuse participation, withdraw, maintain anonymity and confidentiality, were respected [4]. Informed consent was obtained by providing participants with an information letter and consent form, such as those shown in Appendix C, Appendix D, and Appendix E. Data management was handled through the interactive platform of the Norwegian Centre for Research Data (NSD)[1], and a notification form outlining our handling of personal data was submitted and assessed by NSD, as shown in Appendix G.

4.1 Research Questions

From the SLR presented in Chapter 3, we identified a lack of existing studies on the use of digital support for climate-neutral, inclusive, and beautiful cities. However, the existing literature indicates that involving citizens in the transition to climate neutrality using mobile applications and means such as gamification and nudging has a positive effect on their behaviour. Furthermore, an interesting finding is that involvement of citizens has been shown to help cities change.

The research objective of this thesis is to investigate how a digital platform,

[1] https://www.nsd.no/en

more precisely a mobile application, should be designed to motivate citizens to make more contributions to a sustainable and inclusive city. Furthermore, we want to investigate how different gamification elements can motivate citizens to change their environmental behaviour, and specifically what gamification elements should be used. By using the design and creation research strategy, our aim is to produce a set of application requirements, a mobile application prototype, and provide initial patterns in citizens' motivation for environmental behaviour change through the use of mobile applications and gamification elements. Based on the research objectives, the following research questions were developed:

- RQ1: How should a digital platform be designed to motivate citizens to contribute to a sustainable and inclusive city?
- RQ2: Which specific gamification elements should be implemented in such a digital platform to make citizens change environmental behaviour?

4.2 Design and Creation Strategy

The general approach chosen to answer the research questions of a project is called a strategy. According to Oates, the design and creation research strategy focuses on the development of new IT products, also referred to as artefacts [4]. Oates also outlines some common types of IT products developed with a design and creation strategy:

- '**Constructs**: the concepts or vocabulary used in a particular IT-related domain.
- **Models**: combinations of constructs that represent a situation and are used to aid problem understanding and solution development.
- **Methods**: guidance on the models to be produced and process stages to be followed to solve problems using IT.
- **Instantiations**: a working system that demonstrates that constructs, models, methods, ideas, genres or theories can be implemented in a computer-based system.' [4, p. 108]

Additionally, Oates highlights some important academic skills that should be applied for a project to be considered as research, and not 'normal' design and creation as typically done in industry projects. These aspects include analysis, explanation, argument, justification, and critical evaluation, and the project also has to somehow contribute to the creation of knowledge. The way these IT products contribute to knowledge depends on which of the three outlined roles the IT artefact plays. The IT product can have one of these roles: it can be the centre of the research project, a tool for something else, or a tangible result of a project where the focus is on the *process* of development [4].

Based on the research objectives, we have chosen only to use the design and creation strategy, as the developed instantiation, in our case the mobile application prototype, and the results of its evaluation, are our main contributions to knowledge. This is generally common in computer science research [4]. We could

have combined design and creation with another research strategy, such as a case study, which could have been interesting for the purpose of testing our prototype in a specific context, but due to time constraints, advice from supervisors, and several prototyping iterations, we chose to only use design and creation.

The following subsections will explain how this research strategy is followed in order to answer the RQs aligned with our research objectives. The different data generation methods will be explained, and their choice of inclusion will be justified. It will be described how a digital solution can be developed in a research-based way, in the form of the planning, development, and evaluation of a functional prototype. Figure 4.1 illustrates the entire research process, including the design and creation strategy, data generation and data analysis methods.

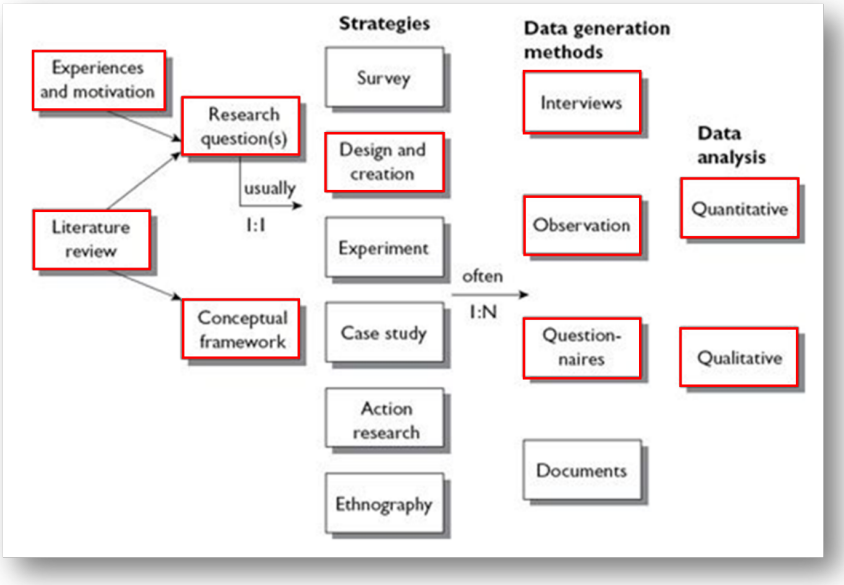

Figure 4.1: Research process based on Oates [4]

4.2.1 The Design and Creation Process Steps

The undertaken activities in a design and creation project must be based on already established principles of system development [4]. In most cases, design and creation is an approach to solving problems, and uses an iterative five-step process. These steps were followed in the process of this project and will be presented theoretically and connected to different activities undertaken at the specific stage in the project. The five-step process followed is shown in Figure 4.2, also showing the different activities carried out at each step.

Awareness This phase regards recognizing and articulating a problem, and this can typically come from literature research to identify paths for further studies, from investigating findings in another field, from practitioners with a specific need, or from technological innovations [4].

The identified problem for this project mainly comes from the SLR [8] summarised in Chapter 3, and from the different background material explained in Chapter 2. The problem has led to the formulation of the research questions and the research objective for this project.

Suggestion This phase regards moving from curiosity about an issue to presenting a tentative proposal of how this issue might be addressed [4].

In our project, this phase included a focus group interview to gather insights, the development of application requirements based on the focus group results, and the creation of initial paper prototypes and wireframes.

Development This phase is where the design idea is implemented, and the specific methodology followed in this phase depends on what kind of IT product is developed [4].

The development phase of the project was done by two iterations of prototype development in Figma.

Evaluation This phase is where the evaluation of the developed artefact takes place, assessing its value and comparing it to the expected outcomes [4].

To evaluate the functional prototype developed, we performed usability tests with, and observation of, relevant participants. Additionally, these participants completed a questionnaire (SUS) to gather data about their experience using the prototyped application.

Conclusion This phase is where the results from the design process are combined, and gained knowledge is identified together with results that cannot be explained and therefore could provide directions for further research [4].

This phase involved presenting the results from the data collected from the focus group and usability testing, also using these results to provide recommendations for further development of the developed product.

4.2.2 Focus Group Interview

The data generation method performed as part of the suggestion step in the design and creation strategy was a focus group interview. A focus group interview is a research method in which a small group of people is brought together with the aim of answering questions in a moderated setting. The questions are intended to

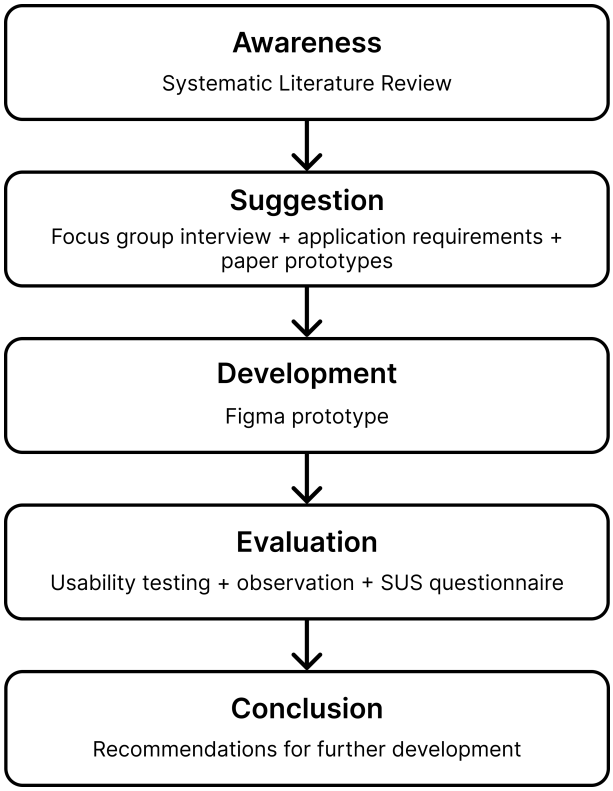

Figure 4.2: Design and creation process steps

provide information on a chosen topic and the group is chosen based on predetermined demographic characteristics[2]. According to Kitzinger, focus groups are a type of group interview that takes advantage of the interaction between study participants to provide data, and the interaction part separates focus groups from other group interviews [70]. According to Wilkinson, a focus group is 'an informal discussion among selected individuals about specific topics' [71, p. 182], outlining that the method usually involves one or several group interviews, where participants focus on a topic chosen by the researcher by discussing a set of questions. Masadeh [72] outlines several definitions and different ways to organise focus groups to generate qualitative data on a specific topic, and this document was deemed a suitable guide when planning and conducting our focus group discussions.

The objective of conducting a focus group interview for this research project was to gain insight into important design aspects when designing a mobile application to encourage citizens to contribute to sustainable and inclusive cities. We used the qualitative data generated from the focus group to guide the design of the mobile application prototype, together with the SLR findings [8]. The focus group discussion conducted in this project aimed to answer the following research

[2] https://www.scribbr.com/methodology/focus-group/

question:

- "What are the design features that a mobile application should have to motivate citizens to actively participate towards a more sustainable and inclusive city?"

Focus group interviews have several advantages, and for our objective, some were crucial when choosing this data generation method. Focus groups can cover a relatively large number of participants in the same session and allow a large amount of data to be collected in a short period of time [72]. It was deemed a suitable data collection technique for our purpose, as it allows us to gather much insight and suggestions on what design features should be used in the early-stage design phase of a mobile application prototype in a short amount of time. The focus group also allowed us to gather opinions and personal experiences from different types of people with different preferences and expertise, and therefore, we have the ability to guide the design of the application. Some potential disadvantages with focus groups, as stated by Masadeh, are that the time and money used for preparations, such as recruiting participants, finding a place to organise the focus group, and equipment for recording and travel, can be far too high for many students and researchers [72]. The following sections outline how we addressed these potential challenges.

Participants

We decided to have six participants for our focus group, as we deemed it an appropriate number for a fruitful discussion with high-quality ideas and less risk of dominant participants creating a competitive environment than in a larger group. Additionally, having a smaller group makes it easier for an inexperienced facilitator to manage and facilitate the discussion [72]. The participants were recruited through a convenience sampling technique, recruiting members from our research group SBS. Convenience sampling involves selecting the nearest, most convenient people as subjects [73], and by using our weekly meeting slot, we guaranteed the accessibility of the participants.

Facilitator and Observer Role

We filled the roles of facilitator and observer, and played a crucial role in the accomplishment of the focus group. Masadeh outlines some suggestions that the focus group should be organised and facilitated by an individual who is not directly involved in the research team, in order to avoid bias. Another paper states that when the researchers use the focus group for the exploration of a topic and therefore do not have a clear vision and opinion, using one of the researchers as the facilitator is not subject to researcher bias [72]. Having one of the researchers as the facilitator is indicated necessary because this person has the best knowledge about the topic, and therefore has the best ability to help the group focusing and keep the sessions on track. This decision was therefore based on our knowledge

about the research, and that we have the best ability to explain the topic and therefore facilitate the best possible discussion.

Length of Session and Location

We decided that a 1-hour focus group was an appropriate length of the session, to meet our objective. The priority when choosing the length of a focus group is to get the maximum amount of information on the topic in minimal time [72], and we did not need more than one hour to facilitate an extensive discussion on each of our questions. In order for focus group discussions to be done properly, the venue in which the discussion is held plays a significant role. The focus group interview took place in a fully equipped meeting room at NTNU in Trondheim, Norway. The choice of this room was deemed suitable due to its modern audio and video equipment, also enabling participants to attend the interview online. Additionally, the room facilitated automatic transcription of the session, enhancing the ease of capturing the discussion. Based on Masadeh's claim, we chose to organise the participants in a circular seating, a method to encourage the participants to engage with and listen to each other [72]. Although the participants were seated in a circular manner, the questions were presented on a large screen visible to everyone, and the facilitator led the session by presenting the questions and facilitating the discussion. The convenient accessibility and usability of this room proved to be time-saving, eliminating the need to spend valuable time searching for a suitable location and ensuring easy access for all participants involved.

Focus Group Questions

The questions asked in the focus group session were developed with the aim of providing as much knowledge as possible regarding our research objectives, thus helping to answer the research questions. The questions were divided into three main topics, namely "Citizen participation", "Usability of mobile applications" and "Gamification". The following list shows the different questions asked in the focus group:

1. Citizen Participation
    a. "*What motivates you to participate in civic activities, such as voting or volunteering?*"
    b. "*What mobile app features or content could contribute to motivate you to make environmental action?*"
2. Usability of mobile applications
    a. "*What types of features can contribute to prevent you from using a mobile application?*"
    b. "*Do you prefer a mobile app with a simple and straightforward design or one with more complex and visually appearing graphics and animations?*"

3. Gamification
    a. "*What types of games or gamification elements do you find most motivating or engaging in mobile applications?*"
    b. "*Do you prefer to receive reminders or notifications from an app, or do you prefer to seek out the app on your own?*"

Pretest

The questions for a focus group are usually pretested in order to establish some important validity considerations [72]. We used the following questions for quality control of our questions, as also pointed out by Masadeh [72, p. 66]:

- 'Is the meaning of the question clear?
- Do the questions use terminology that is understandable to the participants?
- Does each question ask only about one topic?
- Do the questions reflect any hidden bias or "lead" the participants?'

In our case, our co-supervisor, who did not attend the actual focus group, also read through our questions and helped us define our final set of questions. There are varying opinions on the ideal number of questions to be asked in focus groups. Most of the literature suggests between 5 and 12 questions but also states that the number of questions depends on the length of the session.

Data Collection

The focus group methodology presented in this section was chosen as a data generation technique, because interviewing, either face-to-face, one-to-many (like in focus groups) or remote, is viewed as the most prominent for qualitative research [74]. The focus group interview followed a semi-structured protocol, where the participants were asked a number of predefined questions, but there was a focus on keeping a conversational form where new questions and discussions could emerge during the session. Compared to other interviewing approaches, semi-structured interviews are less intrusive to the interviewees due to conversational two-way communication, and can provide confirmation of existing knowledge while at the same time giving an opportunity for learning [74].

The focus group was held as a group discussion where the facilitator presented a set of PowerPoint slides with the questions and asked those questions to the participants. The participants then had time to answer and also discuss and ask questions. In order to collect as much relevant data as possible, the predefined questions aimed at being open and facilitating discussion and personal opinion.

The focus group discussions were held in English, as many of the participants did not speak Norwegian. For transcription, we used Microsoft Teams'[3] automatic transcription tool and the observer took manual notes. According to Krueger and Casey, note-taking is the primary responsibility of the assistant facilitator, and the

[3] `https://www.microsoft.com/en-us/microsoft-teams/group-chat-software`

facilitator should not take notes during the discussion [75]. We followed a similar approach, where the facilitator asked the questions and organised the discussion, while the observer took notes. The observer had focus on writing as clear and consistent notes as possible, outlining key points of the discussion. These notes also worked as a backup for the automatic transcription, and the manual and automatic notes were merged shortly after the focus group.

Data Analysis

We used thematic analysis for the focus group interview's data analysis, as described in detail in Section 4.3.1.

4.2.3 Development Methodology

The development phase of this design and creation research project consisted of the creation of a functional Figma prototype. The prototype was developed to understand how an inclusive mobile application can be used to promote the change of citizen environmental behaviour. The developed prototype is presented in Chapter 6, while this section presents the development methodology.

The prototype development started with the generation of ideas through the use of brainstorming. After accessing different idea-generation methods, brainstorming was deemed the most suitable for our project, due to a limited time-window, previous experience and knowledge, and the wish for an easy and creative method to quickly generate ideas for our application. As outlined by Han *et al.* [76] the lack of relevant information might be a problem when generating ideas, but the focus group interview presented in Chapter 5, in addition to the SLR presented in Chapter 3 and the theoretical grounding presented in Chapter 2 helped solve this problem for our purposes.

We conducted two brainstorming sessions, both of which were conducted after the focus group interview. We conducted the first session alone, while the second session included two members of the SBS research group. The objective of the second session was to gather feedback on the ideas of the first session and collectively come up with new ones. We decided on a digital approach to brainstorming and used Miro[4], a digital tool with many opportunities when it comes to brainstorming and grouping ideas. Although the brainstorming process appears to be the final activity in professional design work that has not yet been fully digitalised [77], the products, that is, ideas produced, seem to be the same whether using an analogue or digital approach. The use of Miro simplified our brainstorming by making it possible to conduct online, while also making it easier to connct theories and insights from the SLR and focus group to the different ideas generated.

After brainstorming ideas for the application, we started the design phase using paper prototypes. Paper prototyping is a widely used methodology for designing, evaluating, and clarifying user interfaces. In its widest sense, the technique

[4] https://miro.com/

can be seen as a method for brainstorming, designing, developing, evaluating, and communicating graphical interfaces [78]. We chose to use paper prototypes as a conceptualisation of ideas from brainstorming, to get a first visualisation of what the actual product could look like and to guide the development of the application requirements presented in Section 6.1.

Based on the results of the focus group interview presented in Chapter 5 and the SLR findings, we developed application requirements for the mobile application. According to Macaulay 'Requirements Engineering is concerned with what needs to be designed rather than how it is to be designed' [79, p. 1], having a critical role in software development [31]. According to Lombriser, many IT projects fail due to wrong or unsatisfied requirements [31], and therefore we decided to develop application requirements to lay a solid foundation for our application. These requirements were made to help answer RQ1 and also to provide a framework for further development of the product. The use of user stories is a popular technique for representing software requirements [80]. There are several different methods to represent requirements, but we chose user stories as our requirement documentation technique for simplicity and comprehensibility reasons [31], especially to make them as understandable as possible for subsequent researchers or others. The simple template 'As a [**role**], I want to [**goal**], so that [**benefit**]' [80], [31], was used when formulating our user stories.

Prototype Development

Prototyping was chosen as the development method to create our design and creation IT artefact. Prototyping is an iterative approach where a first version is made and tested, and then a revised prototype can be made based on the evaluation of the first version [4]. Therefore, there is no need to be fully aware of the problem before starting to explore solutions. For our purpose, we wanted to test a concept and be able to iterate in a relatively short amount of time, and therefore prototyping seemed appropriate for our purpose.

We started prototyping by creating initial wireframes in Figma. The prototyping tool in Figma provides the possibility of making interactive prototypes that feel like a real application, and when running iterative design processes with constant building, testing and iterating, the prototyping tool makes it easy to test the solution early in the design process[5]. According to Snyder, a wireframe outlines a website's page layout and indicates where the content will appear on the page [78], and we created such wireframes for our mobile application prototype. The initial wireframes of the mobile application were based on the previously mentioned application requirements. The wireframes focused on being as primitive as possible, only outlining the most important functionality based on the application guidelines.

After paper prototyping and digital wireframing, a more detailed prototype was developed, based on application requirements, wireframes, and the theoret-

[5] `https://www.figma.com/prototyping/`

ical framework. Figma makes it easy to design testable user interfaces without programming. Therefore, these prototypes provide a way to test important features of the application early on. This prototype aimed at covering the most important design and features to include in the application, to be able to test on users early on in the development process. Figure 4.3 shows an overview of our Figma project.

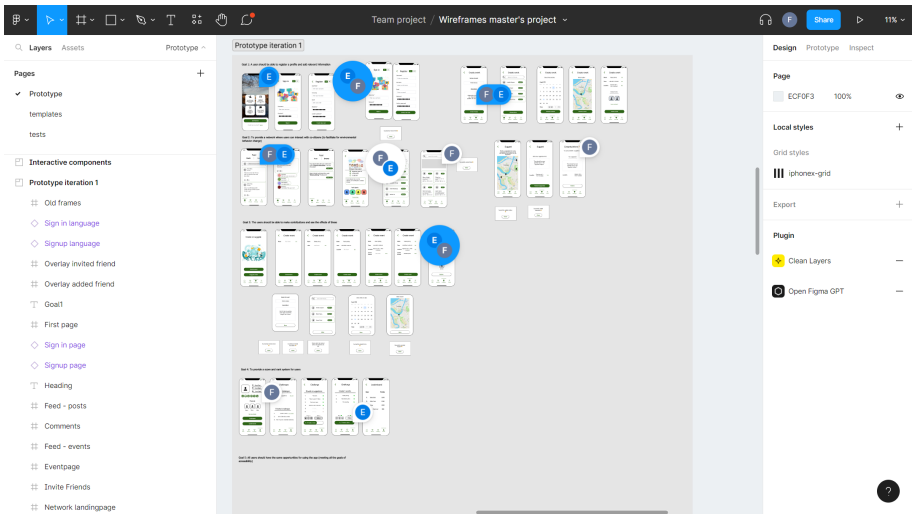

Figure 4.3: Figma overview

The development was done in an iterative way, and we conducted two iterations of planning, development, and evaluation of the prototype. The development in the first iteration was mainly based on the application requirements and design choices presented in Chapter 6, and in the second iteration, development consisted of implementing changes based on feedback from the first iteration of usability testing. The following section describes our chosen prototype evaluation methodology.

4.2.4 Usability Testing

In the evaluation phase, the developed mobile application prototype was evaluated after each of the two development iterations was completed. There are many ways to evaluate an IT artefact, depending on the research objective. We chose to use usability testing, as it was deemed a suitable technique to test our prototype on target users. Usability testing is performed at all stages of a design process, and the best results are achieved using prototypes, due to the immediate response and value given to developers[6]. The data generation methods used as part of the usability testing sessions were a "think-aloud" methodology, observation of how the participants interacted with the prototype, the SUS questionnaire, and interview questions, and the results of these methods are presented in Chapter 7.

[6] `https://www.toptal.com/designers/prototyping/user-testing-prototypes`

According to Moran, Vice President of the Nielsen Norman Group, a leading research-based firm in the field of UX, usability testing is conducted for three different reasons. First, the researcher wants to uncover design problems by evaluating how a user interacts with an application, second, the researcher wants to discover opportunities to improve the solution, and last, the researcher wants to learn about the users [81]. Specifically for our research purpose, we wanted to identify problems in the design to provide a proposed design for the mobile application, we wanted to learn about the participants by investigating their motivational factors and how they interact with the application, and discover opportunities by receiving suggestions from the participants.

Participants

We decided to have 7 participants for each iteration of usability testing. Nielsen outlines that 5 users are a good number for one iteration, as after the fifth user, you will often observe the same findings again and again. Nielsen further outlines the need to use iterative design, as at least 15 users should be tested to discover all usability issues [82]. However, due to the time constraints, and because the participants also answered the SUS and some interview questions after the usability test, we decided that a total of 14 users would give us results with high validity and complementary insights.

We did not apply strict limitations for recruiting participants for the usability testing of our mobile application prototype, as we initially aimed to investigate the motivational and behavioural aspects of individual users. Therefore, we chose to use convenience sampling to select users for our usability tests. As mentioned previously, this sampling technique involves selecting the nearest, most convenient people as subjects [73], and was followed in both iterations. Although we used convenience sampling, we aimed to be inclusive as we also tried to balance the age and gender of our participants, and we also had participants from different nationalities. Given the unique opportunity to engage in a mobility trip to Manaus, Brazil with the SENOBR[7] project, exchanging experiences and practises in software engineering between Norway and Brazil, we got to carry out Iteration 1 of usability testing with local UX experts there. These participants were members of a Brazilian research group named USES[8], a research group focusing on usability and software engineering seeking to provide ground-breaking solutions in the fields of software engineering and human-computer interaction. Given our research objective focused on designing a mobile application, it appeared beneficial to involve researchers with expertise in usability and UX for the initial prototype evaluation. Their involvement allowed us to gather early and valuable design feedback, which played a crucial role in guiding the development process. According to Oates [4], a research project has space triangulation if the study takes place in two or more countries to avoid the narrowness of the study based in only

[7]https://www.ntnu.edu/idi/senobr
[8]https://uses.icomp.ufam.edu.br/

one country. For Iteration 2 we recruited master's students from different areas of study at NTNU as participants. As we had participants of different nationalities, we got important insights from another part of the world. This has given much value to the project, as the main objective is to contribute to a global issue, and cooperation and shared practices are important for everyone to achieve climate goals.

Facilitator and Observer Roles

We filled two different roles when conducting usability tests. One of us served as the moderator and had the responsibility of communicating with the participant. This involved presenting the project and the information letter, presenting the scenario and tasks, and explaining how we wanted the participant to carry out the tests. The moderator also explained the SUS and asked the final interview questions to the participant. The one of us not being the facilitator had an observer role during the usability testing sessions, involving the responsibility of recording, observing, and taking notes throughout the entire session. As participants were asked to think aloud when performing the test tasks and also when filling out the questionnaire, the observer took notes along the way, outlining the seemingly most important suggestions and feedback from the participants. This was done both as a backup to the audio recording and because it is easier to catch the underlying emotion of what a person is saying when actually sitting in the same room rather than just listening to an audio recording. All usability tests were recorded and automatically transcribed using Microsoft Teams and Word.

Location

Iteration 1 of usability testing was conducted in Manaus, Brazil, as a part of the "Wonders workshop" - a workshop on diversity in Science, Technology, Engineering, Art and Math (STEAM). We conducted the tests in an office at the UFAM[9], and the setup was done in a simple way using only a round table where the facilitator and observer could observe the user performing the test.

The study site for Iteration 2 was a UX laboratory at NTNU in Trondheim. The main advantage of such UX laboratories is that users and facilitators can focus solely on the test tasks, while spectators can follow the session from a separate observation room [83]. The main difference between conducting usability tests in a simple office and in a laboratory was the use of multiple cameras. In the UX laboratory, we organised the room in a similar way as in Iteration 1, but we used the available video equipment for the observer to be able to observe the participants while they did the test, without having to sit in the same room. High-quality video and audio equipment also simplified the transcription process, and the video recordings made it easy to go through the recordings and also to make observations of the participants' interaction. The setup of the usability testing lab

[9] https://www.ufam.edu.br/

is shown in Figure 4.4, also illustrating the camera views that the observer could see during the tests.

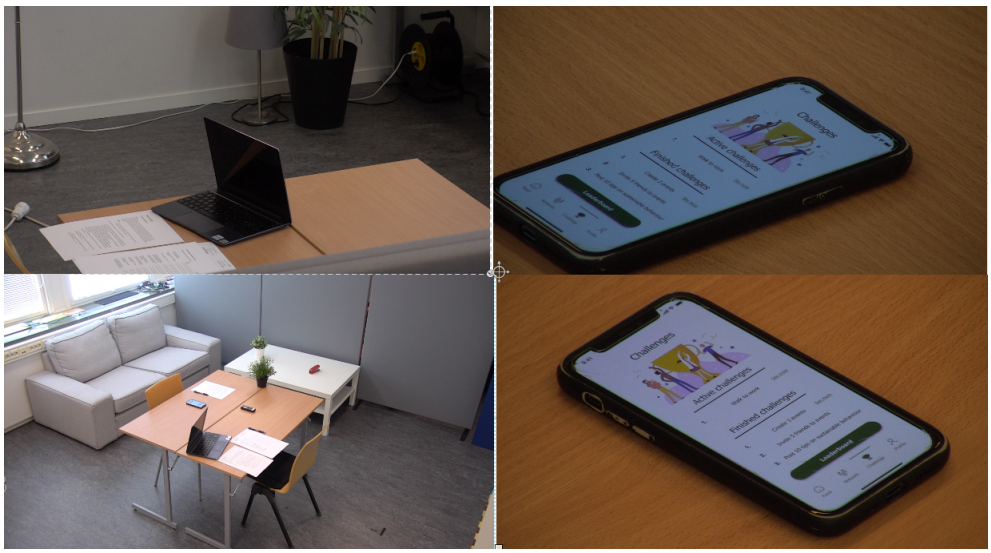

Figure 4.4: Test setup at the UX Lab in Iteration 2

Conduction

The usability test was initiated by the facilitator who presented the scenarios and tasks to the participant on a piece of paper. The user was then asked to start the run-through of the application while thinking aloud, guided by the scenario and the tasks presented on paper. According to Nielsen, thinking aloud offers several advantages and is considered a fundamental tool in any researcher's UX toolbox. It provides researchers with information on users' genuine thoughts on design and helps uncover any misconceptions they may have, often leading to redesign recommendations [84]. The participants were also informed that all thoughts and observations about the application could be valuable, encouraging the participants to provide feedback along the way. In this way, we were able to watch participants use the application, which is considered the essence of usability testing by McCloskey [85]. Additionally, participants were informed that they would not receive any help from the facilitator during the test. The test was carried out using an iPhone 11 Pro mobile device with the prototype open in the Figma app[10].

The main part of the usability testing consisted of the participants being presented with a scenario and several activities to get insights into how they interacted with the application and what was causing them problems when using the application. The tasks for the usability testing were developed as a way to provide context and are closely related to the goals of the application. McCloskey [85] outlines three task-writing tips to improve the outcome of usability tests:

[10] `https://apps.apple.com/us/app/figma-and-figjam/id1152747299`

1. Make realistic tasks
2. Make actionable tasks
3. Make tasks without giving clues and describing steps

The purpose of our provided scenario was to provide context to the participants and to outline the motivation for why the participant should be using the application. The following scenario was presented to the user:

"You live and work in a city, and you care about climate change and the future of the planet. Nevertheless, you struggle to motivate yourself to take real action, and you don't know how to connect with like-minded people to contribute more. You will use the mobile application presented to get a network of people with the same interests, make actual contributions and see the effects of these contributions in comparison to what others have done."

The aim of the tasks was to get users to interact with the most important functionality in the application and to get valuable feedback on what should be improved. The tasks also aimed to show the user the possibilities and options of using the application. The following tasks were presented to the participants:

1. *Get started with the application by signing up. Check that all of the personal information is filled in before creating the user.*
2. *Navigate to the "network" tab, and add Mason, Olivia and Sofia as friends.*
3. *Go back to the feed and locate the event "Climate Discussion". Invite Naomi Patel to this event.*
4. *Go to the "Create" tab, and create an event where you choose name, time and location. Invite Amelia Grayson to the event.*
5. *Suggest an action for a more sustainable city.*
6. *Find your active and finished challenges on your profile. See how many tasks you have finished on the "Suggestions" challenge. Locate the finished challenge "Create 3 events" and see how many points and badges you received for finishing this challenge.*
    a. *How many tasks have you finished in the suggestions challenge?*
    b. *How many points did you gain for completing the "Create 3 events" challenge?*
    c. *How many badges for completing the "Create 3 events" challenge?*

One of the advantages of doing iterative usability testing is that we were able to improve the usability test guide based on user experiences, theory, and feedback before Iteration 2. One of the changes we made was renaming "tasks" to "activities", to avoid the possibility that users would feel uncomfortable about being tested [85]. We also decided to rephrase some of the activities to avoid giving clues to users and make the interaction with the application more realistic. The following activities were presented to the participants in the second iteration:

1. *Get started with the application by signing up. Check that all of the personal information is filled in before creating the user.*
2. *Navigate to the "network" tab, and add Mason, Olivia and Sofia as friends.*

3. *Go back to the feed and locate the event "Climate Discussion". Invite Naomi Patel to this event.*
4. *Go to the "Create" tab, and create an event where you choose name, time and location. Invite Amelia Grayson to the event.*
5. *Suggest an action for a more sustainable city.*
6. *Find your active and finished challenges on your profile. See how many tasks you have finished on the "Suggestions" challenge. Locate the finished challenge "Create 3 events" and see how many points and badges you received for finishing this challenge.*
    a. *How many tasks have you finished in the suggestions challenge?*
    b. *How many points did you gain for completing the "Create 3 events" challenge?*
    c. *How many badges for completing the "Create 3 events" challenge?*

The usability test sessions were concluded with a couple of interview questions to get more insights into the participant's motivation for using the application and suggestions for improvement of how the application could be improved to increase motivation. These interview questions were designed to provide more information on the motivational aspects of the participants, helping answer our research questions. Also, these questions aimed at helping us to understand the thoughts of specific questions related to our research questions that might not have been answered during the "think-aloud". The following interview questions were asked:

- "*Do you see yourself becoming more motivated for environmental behaviour change after using this mobile application? Why, why not?*"
- "*Did you miss any feature that could have made you more motivated?*"
- "*Are there any specific gamification elements you can highlight as especially motivating for you, which can motivate you to use this app regularly and change your environmental behaviour?*"

Data Analysis

The data analysis procedure followed for the qualitative and quantitative data collected from usability testing is described in detail in the following section.

4.3 Data Analysis Methodology

The following sections will explain the different data analysis methodologies followed in this project, namely the methods chosen for qualitative and quantitative analysis.

4.3.1 Qualitative Analysis Method

The large amount of information that must be analysed during the data analysis phase is one of the fundamental characteristics of qualitative research. Typically, this analysis is done without a clear understanding of why or which parts are relevant or not to the outcome [74]. There are many different techniques to analyse qualitative research data.

"Themeing of data", or "thematic analysis" as we will refer to it, was chosen as our qualitative analysis method. Such a methodology is also presented as the "Analysing Textual Data" methodology by Oates [4]. We followed this methodology by categorising our collected qualitative data into *themes*, namely an *extended phase* or *sentence* to identify what the specific unit of data *means* and what it is *about* [86]. Some of the advantages highlighted by Braun and Clarke [87] played a significant role in our choice of thematic analysis to analyse our qualitative data. First, as we do not have much experience with qualitative research, we wanted a flexible and easy-to-learn methodology so that we could get going quickly and not use too much of the restricted time to master the methodology. We also wanted to find the key features of our collected data based on our research questions and the theoretical framework, and based on these requirements thematic analysis seemed a good fit for our purpose. According to Braun and Clarke, thematic analysis is also a practical and adaptable approach to qualitative research within and outside psychology [87]. Furthermore, as Saldaña outlined, themeing of data is a suitable way to analyse data from participatory data collection methods [86], also providing justification for employing this method.

Some researchers doubt the ability of thematic analysis to produce high-quality data for exploratory qualitative research, but Vaismoradi *et al.* highlights that thematic analysis is a robust enough method for carrying out an initial study on a novel phenomenon, where the quality of the data is dependent on the researcher's effort and time put into the data collection and analysis procedure [88]. They also outline that thematic analysis is recognised as one of the easiest qualitative research approaches, but that the user-friendly data analysis method is a good fit for researchers early in their research careers. Rosala also identifies thematic analysis as a methodology that is often used to analyse data gathered from UX research [89]. Therefore, thematic analysis was chosen as the data analysis method for this research project.

We chose to follow a theoretical approach, also called a deductive approach, which means that we had predefined themes retrieved from the existing literature based on the specific research questions of the project. The reasoning behind this decision is that we have a theoretical framework with existing theories from the literature and we want to search for patterns in the data based on these theories. The themes we used were made for our specific research questions, and therefore, we focus our analysis on the relevant data segments concerning these questions. Naturally, we then provide a more detailed description of some aspects of the data, namely, the parts deemed relevant to our research objective.

Braun and Clarke outline different phases of a thematic analysis and their descriptions [87]. We followed this step-by-step methodology because it made it easy for us to deal with the same guidelines for each of the iterations we performed the data analysis. The step-by-step guidelines for doing thematic analysis are shown in Table 4.1.

Analysis phase	**Description**
'Familiarising with data	Transcribing data (if necessary), reading and re-reading the data, and noting down initial ideas.
Generating initial codes	Coding interesting features of the data systematically across the entire data set, collating data relevant to each code.
Searching for themes	Collating codes into potential themes, gathering all data relevant to each potential theme.
Reviewing themes	Checking if the themes work in relation to the coded extracts and the entire data set, generating a thematic map.
Defining and naming themes	Ongoing analysis for refining the specifics of each theme and the overall story that the analysis tells, generating clear definitions and names for each theme.
Producing the report	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a report of the analysis.'

Table 4.1: Thematic analysis from [87, p. 87]

For the first analysis phase, namely *familiarising with data* we combined our automatic transcriptions through Microsoft Teams and Word, and the notes of the observer, to combine all data from each participant. Then we read through each of the files, aiming to get a general impression of each transcription, and also to fix errors in the automatic transcription by re-listening to the audio recordings. In this way, we made sure that all the documents from each participant were on the same form before starting to generate codes. The methodology of Oates to identify key themes in the data was used to filter out irrelevant segments before coding. We only kept segments from the third category, those appearing to be relevant to our research questions:

- 'Segments that bear no relation to your overall research purpose so are not needed (at least for the current study)
- Segments that provide general descriptive information that you will need in

order to describe the research context for your readers (for example, history of a company, number of employees, location, time your respondents have spent in their current job role).
- Segments that appear to be relevant to your research question(s).' [4, p. 268]

The next phase of the step-by-step guide from Braun and Clarke involves *generating initial codes*. Coding is a way to analyse qualitative data, using small words or phrases called *codes* to assign some kind of attribute to a segment of data [86], [89]. We chose to do the coding in a manual way, although we used digital files but not dedicated analysis software. Manual coding is found to allow ease of access, flexibility, and creativity that the analysis software does not allow [90]. We chose descriptive coding as our coding method. 'Descriptive Coding summarizes in a word or short phrase - most often as a noun - the basic topic of a passage of qualitative data'[86, p. 88]. Therefore, we worked through the transcripts of each participant and coded relevant segments of the data based on the topic. The most important thing about this coding method is that it identifies the topic of the data, specifically the essence of what our participants were talking *about*. We chose this coding method because it is appropriate for inexperienced qualitative researchers new to coding data, and can also be applied to many different data forms, such as interview transcripts and video recordings [86], [91]. Furthermore, the fact that descriptive coding helps identify keywords [91], made it applicable to our thematic analysis.

The next step involved *searching for themes*. In this phase, we combined the coded data segments into themes, and we used predefined themes retrieved from the existing literature based on the specific research questions of the project. The specific themes used were slightly different for each of the data generation methods and are shown in the results tables in Chapter 5 and Chapter 7. Next, we did *review of the themes* and *defining and naming of themes*, where we checked that all themes represented the data set, and we also moved the data to Miro[11], to visualise themes and related data segments. A visualisation of one of the categories before further grouping is shown in Figure 4.5, and the same category after further grouping is shown in Figure 4.6.

Lastly, we combined the themed data with relevant theory and literature, to prepare the data to *produce the report*. The results of the thematic analysis done for the focus group interview are shown in Chapter 5, and for the usability tests in Chapter 7.

4.3.2 Quantitative Analysis Method

The SUS [92] was used to evaluate the usability experience with the prototype in a quantitative way. The scale was chosen as it is reported to be a reliable tool for measuring the usability of a system, according to Bangor *et al.* [93], thus being appropriate to achieve our research objective. It is a 10-item questionnaire to measure usability, and in the usability testing participants were asked to complete

[11] https://miro.com/

Figure 4.5: Data analysis in Miro

this questionnaire directly after finishing the tasks. The questionnaire can be found in Appendix F. For each question, the user has five answer options: 'Strongly Disagree', 'Disagree', 'Neutral', 'Agree' and 'Strongly Agree', corresponding to a score from 1 to 5 respectively. The final score of the SUS is measured using the steps described in [69, p. 7], presented below:

1. 'Add all the scores for the odd-numbered questions (1, 3, 5, 7, 9) together and subtract 5 from this.
2. Add all the scores for the even-numbered questions (2, 4, 6, 8, 10) together and subtract this number from 25.
3. Add the scores calculated in steps 1 and 2 together and multiply by 2.5.'

Bangor *et al.* [94] have mapped the SUS scores to a scale of describing adjectives, and the scores obtained in the usability testing will be compared to these. The rankings are the following:

- Worst imaginable = 12.5
- Awful = 20.3
- Poor = 35.7
- OK = 50.9
- Good = 71.4
- Excellent = 85.5
- Best imaginable = 90.9

In addition to calculating the average score for each participant in the usability test, the average score per question was also calculated, and compared to benchmark values found by Lewis [95]. These benchmark values can be used to

Figure 4.6: Data analysis in Miro (2)

extract meaning from the individual SUS questions. We compare our results both to benchmarks to gain an average total SUS score, and to benchmarks to gain an above-average total SUS score.

Confidence intervals have also been calculated for the mean scores following the approach of Sauro and Lewis [96, Example 1]. The mean and standard deviation have been computed, followed by using the t-distribution to present the confidence interval, as this is the best approach for constructing a confidence interval around numeric rating scales [96, p. 26]. The standard deviation has been calculated by using the formula for standard deviation of samples[12]:

$$\text{Sample Standard Deviation} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

where n is the sample size, x_i represents the SUS score for each participant, and $\bar{x}$ represents the mean SUS score for each iteration. The confidence level used is 95%, as this is the typical value when reporting a confidence interval [96, p. 20]. The t-critical value was found by the Excel formula = TINV(0.05, 6), specifying the level of significance used (1 minus confidence level) and degrees of freedom (sample size minus 1).

[12] https://www.ncl.ac.uk/webtemplate/ask-assets/external/maths-resources/statistics/descriptive-statistics/variance-and-standard-deviation.html

Chapter 5

Focus Group Interview

This chapter presents results from the focus group interview conducted as one of the data generation methods for the design and creation research strategy from Oates [4]. The objective of the conducted focus group was to gain insight into important design aspects when designing a mobile application to encourage citizens to contribute to a sustainable and inclusive city. The focus group interview was part of the "suggestion" step of the iterative design and creation approach. The entire focus group methodology is presented in Section 4.2.2. The results presented in this chapter were used to guide the development of the application requirements and design of the developed mobile application prototype presented in Chapter 6, together with the findings of the SLR [8] and the theoretical foundation. The results regarding RQ1 are presented in Section 5.1.1, and the results regarding RQ2 are presented in Section 5.1.2. Finally, tables showing all the results from the thematic data analysis are presented.

5.1 Results

The following section presents the results from the focus group interview, aiming to answer the focus group research question "What are the design features that a mobile application should have to motivate citizens to actively participate towards a more sustainable and inclusive city?", mainly to help answer RQ1 and guide the development of the mobile application prototype presented in Chapter 6. However, the results from Question 5 regard gamification elements that support answering RQ2.

5.1.1 RQ1: How Should a Digital Platform Be Designed to Motivate Citizens to Contribute to a Sustainable and Inclusive City?

Motivation factors

The first question asked in the focus group and the first in the category *Citizen participation* started a discussion with several different responses. Participants 2

and 4 highlighted the social aspect as an important motivation factor for them to participate in voluntary initiatives. The value of being together about something and being able to share a passion for the same topic was something that several of the participants outlined.

Another motivational factor that was highlighted was that the volunteer work should be flexible and that the participants should not feel high pressure to participate, as highlighted by both Participants 5 and 6. There seemed to be a broad agreement that flexibility is very important for motivation and contribution. Participant 5 also highlighted the motivational element of feeling like you are contributing to something that actually makes a difference. All the answers to this question can be found in Table 5.1.

Mobile app features for motivation

The second focus group question went into more detail about what mobile application features could contribute to motivating participants to take environmental action. Many of the answers correlated with the answers from Question 1, Participant 4 summarised: *'Again, it's just connecting with people and see if you can do something that is small but has a value'*. The importance of highlighting the problem in a tangible way, in a way the user can relate to, was very important according to Participant 3. Participant 1 highlighted gamification elements in applications as an important motivational factor. All the answers to this question can be found in Table 5.2.

Design Features to Prevent Users from Using a Mobile Application

The third question, and the first in the category *Usability of mobile applications*, was about the design features of a mobile application that could prevent users from using the application. Both the negative and positive sides of notifications and pop-ups were discussed, as some of the participants outlined that they sometimes find notifications helpful, while others sometimes found them annoying, especially if they have stopped using the app and they still receive e-mails to try to lure them back. Participant 5 highlighted the use of dark design and manipulation, or the feeling that an application collects a lot of sensitive data, as a factor that could prevent this participant from using it. Participant 2 highlighted that the choice to not use an app anymore often comes down to whether the application is engaging enough and the options of the application, rather than specific features. All the answers to the third question can be found in Table 5.3.

Design Preferences

The fourth question asked was in the category "Usability of mobile applications", and regarded whether the participants, in general, preferred a simple and straightforward design or a more complex one with graphics and animations. The participants did not have many answers to this question, but there were some opinions

on when the design should be more complex. Participant 2 highlighted graphics and animations as good elements to use for storytelling and to keep the user engaged, and Participant 1 outlined complexity and animations for socially geared apps or apps using gamification as positive elements. All the answers to this question can be found in Table 5.4.

Notification Preferences

Notification preferences were also discussed in whether participants preferred to receive reminders or notifications from an app or not. Participant 2 outlined that notifications can be present in an app, but if there are too many, this causes anger and deletion of the app. Participant 1 highlighted the need for user moderation of what notifications should be received and what should not. All the answers to this question are shown in Table 5.6.

5.1.2 RQ2: Which Specific Gamification Elements Should Be Implemented in Such a Digital Platform to Make Citizens Change Environmental Behaviour?

Motivating Gamification Elements

The fifth question regarded what gamification elements the participants find most engaging in a mobile application, and therefore help answering RQ2. The participants mentioned many different gamification elements which can help motivate them. Participant 3 highlighted rank, leaderboards, and rewards, Participant 4 outlined a preference for short games that can be played whenever reasonable, Participant 6 outlined levels as a motivational element, Participant 5 highlighted some features that show how much of a given task has been completed as motivating, Participant 2 highlighted the importance of how the game is connected to the actual goal that is pursued, and Participant 1 outlined point systems. In summary, the participants had many different opinions on which gamification elements were motivating, but seemed to agree that gamification is motivating if used in a reasonable way. All the answers to this question are shown in Table 7.2.

Data segment	Themes
Participant 1: "*One thing could also be that during the pandemic we were able to travel less. So we felt like we were also maybe doing more (for the climate) and then by 2021 people started travelling again and which isn't that great for the climate obviously. Also, that there were just like sick of it and the fact that it saw how like climate change is reduced when China can't produce as much anymore during COVID and maybe saw that what we're doing might not effect as much as what they're doing over there*"	- Motivational factors for behavioural change - Citizen participation
Participant 2: "*So for me in general it's related to the values and the things that I believe in. But it's also about people joining at the events as well, for example, if I am passionate about a topic and I see an event that I like and I know there are some people that I know there, I join.*"	- Motivational factors for behavioural change - Citizen participation
Participant 2: "*I like to share activities with them.*"	- Design features to motivate citizens
Participant 2: "*It was easier for me to do that when I was back in my home country because I knew many environments and where people gather, so I could join more easily.*"	- Motivational factors for behavioural change - Citizen participation
Participant 4: "*I think like the social aspect of the ones sharing is important. Just like as you said. To meet more people and kind of being together*"	- Motivational factors for behavioural change - Citizen participation
Participant 3: "*For me, its motivating to wanting to make a change, so when I noticed that there's something wrong, then instead of, you know, waiting for it to be solved, somehow trying to be part of the solution*"	- Motivational factors for behavioural change - Citizen participation
Participant 5: "*And also that it is low pressure. So you can participate in it when you have time, and don't need to use a specific amount of time every week for example*"	- Motivational factors for behavioural change - Citizen participation
Participant 5: "*Also can be motivating to know that the things you are doing actually can make a difference. And so that you know that, you do it to help and not just it doesn't matter*"	- Motivational factors for behavioural change - Citizen participation
Participant 6: "*The volunteer work should be more flexible. If I feel like I'm bound to do this, then maybe it will not interest people to come for the work, so it should be a bit flexible.*"	- Motivational factors for behavioural change - Citizen participation
Participant 6: "*The communication part is also important. To get opportunity to volunteer for something, I need to know about it more. So that kind of information communication that's also very important.*"	- Motivational factors for behavioural change - Citizen participation

Table 5.1: Table of themed data segments related to motivation factors

Data segment	**Themes**
Participant 3: "*I think it is important for the mobile app to have some information about the problem. What is the problem? But I think also in a solvable way. So if it says that like the ice cap is melting, I don't feel that I have anything to do with it, and nothing I can do for it. So make it like simple that I feel that I can contribute to*"	- Design features to motivate citizens - Motivational factors for behavioural change
Participant 2: (on an app where you can buy a tree and follow the status) "*I think it's a small little reward, but it works because when you think of environment as an asset, it's more like a big, enormous change. I don't know what my impact could be.*"	- Motivational factors for behavioural change
Participant 2: "*And there is like lots of like really cute graphics all the time and also positive interventions like people that communicate or just say small stuff like you should close your water when you're washing your feet.*"	- Design features to motivate citizens
Participant 1: "*It would be either more like infomercial style, but it also maybe with some gamification elements. . . . but I feel like gamification elements kind of motivates me at least*"	- Design features to motivate citizens - Gamification elements
Participant 4: (about an app) "*Again, it's just connecting with people and see if you can do something that is small but has a value.*"	- Motivational factors for behavioural change - Citizen participation
Participant 6: "*I just found out something that I think is also necessary too, for example, if you're using any scenario or example in app. Think it's necessary for people that they can relate to what most of the people can relate to themselves with those scenarios or examples. . . . But I don't think many people think about this kind of wastage and examples when we think about environmental effects from activities, so this kind of examples with people can relate to their daily life.*"	- Motivational factors for behavioural change - Citizen participation

Table 5.2: Table of themed data segments related to mobile app features for motivation

Data segment	Themes
Participant 1: "*I guess one thing is like this those apps that have like ads popping up all the time or just like super annoying pop up elements in general.*"	- Design features to motivate citizens
Participant 2: "*In general if I don't feel like using an app anymore, it's mostly because I'm bored, not because they do something that like annoys me, so it's a matter of how engaging the application is and what can I do with the application.*"	- Design features to motivate citizens - Motivational factors for behavioural change
Participant 2: "*So if you decide that an app should be used two times a day, then it should be designed to being used two times a day*"	- Design features to motivate citizens
Participant 3: "*I really hated that when I stopped using Duolingo for Norwegian, it still continued sending me emails. 'Ohh you're letting us down'. It was annoying.*"	- Design features to motivate citizens
Participant 2: "*So if you dont use it, then it can be annoying. But if for example I get a notification because of an update of something that I like, I will open it and check out the update. I like this use of notifications*"	- Motivational factors for behavioural change - Design features to motivate citizens
Participant 6: "*For me, these notifications from Duolingo sometimes helps. If i forget to use the app for some days, and I get a notification saying "Are you forgetting us? Why dont you use Duolingo?", then i remember that I should use the app, and use it. So for me it works sometimes*"	- Motivational factors for behavioural change - Design features to motivate citizens
Participant 3: "*I agree that it is good with notifications when you want to keep the streak, but when I have decided that I want to stop using the application, it is annoying*"	- Design features to motivate citizens
Participant 5: "*I think if an app has some kind of dark design and is trying to manipulate you, or if you feel that the app is collecting a lot of sensitive data about you, then I don't want to use that*"	- Motivational factors for behavioural change - Design features to motivate citizens

Table 5.3: Table of design features to prevent users of using an app

Data segment	Themes
Participant 2: "*For storytelling I like graphics and animations, because they keep you engaged, just like Duolingo*"	- Design features to motivate citizens
Participant 1: "*If the app is a socially geared app or one with gamification elements, I would like it to be more complex and have animations.*"	- Gamification elements

Table 5.4: Table of design preferences

Data segment	**Themes**
Participant 3: "*For example in Duolingo, I find it good to have gamification elements like the ranks, leaderboards and rewards*"	- Gamification elements - Motivational factors for behavioural change
Participant 3: "*I don't know how specific this is to language learning, but I felt that sometimes gamification overrode the initial function of the specific app. Because sometimes I just did the practice in order to gain points, instead of focusing on what will benefit my language learning. So sometimes I mean it helped me keep my streak and if you say that for language learning it is important to have consistency, then it is good. But I have mixed feelings about gamification*"	- Gamification elements
Participant 4: "*I think I prefer games that are short, so I can play them whenever I want to.*"	- Gamification elements
Participant 6: "*If the game has multiple levels, then maybe I'll feel the push to have to go to the next level. So there is some motivation to play the game and finish the game so I can move forward*"	- Gamification elements - Motivational factors for behavioural change
Participant 5: "*I prefer some features that show how much you have completed. For example, if it's a game about steps, if you want to go 10000 steps each day, then you can see how many steps you have left in a sort of progression bar. To see the percentage you have left to complete a task, I think that is really motivating*"	- Gamification elements - Motivational factors for behavioural change
Participant 2: "*What is important for my motivation is how the game is linked to the actual goal that I am pursuing*"	- Motivational factors for behavioural change
Participant 1: "*I am quite fond of point systems, especially when the points correlates with, say the size of the task that you are doing. In that way, you know that some tasks are more impactful than others*"	- Gamification elements

Table 5.5: Table of themed data segments related to motivating gamification elements

Data segment	**Themes**
Participant 2: "*I can have notifications, but if they are too many, I get angry and just delete the app*"	- Design features to motivate citizens
Participant 1: "*I think the user should have some kind of options to set the notifications settings. If I want notifications, I can switch it on if I don't want it then I keep it odd. It should also be possible to choose what kind of notifications you get.*"	- Design features to motivate citizens

Table 5.6: Table of themed data segments related to notification preferences

Chapter 6

Mobile Application Prototype

In this chapter, we present the digital solution developed as the IT artefact in the design and creation methodology presented in Chapter 4, that is, a mobile application prototype to help answer our research questions and guide future development. Section 6.1 presents the developed application requirements and Section 6.2 presents the developed mobile application prototype. Section 6.3 presents changes to the prototype between iterations of usability testing, Section 6.4 presents a proposed technology stack for development of the application, and Section 6.5 presents similar solutions.

The idea generated from the brainstorming is to create a mobile application to motivate citizens to take action on climate change. Paper prototypes, initial wireframes, and a mobile application prototype were developed to implement and test this idea against relevant users and to provide guidance for further development, both when it comes to design and concepts that should be included in the application. Both the concept of challenges, gamification elements, and the social aspect were included with the intention of driving individual behaviour change, supported by the literature and the focus group.

6.1 Application Requirements

The developed application requirements, made to guide the design of the application and also provide a framework for further development are presented in this section. The developed requirements consist of 5 goals, which were formulated as they are deemed necessary for the execution of our idea. Each goal is accompanied by several user stories.

Goal 1

The first goal regards making it possible for users to register on the application, to be able to meet the second goal of connecting with other users and creating a network. The importance of this goal is supported by both the literature and the focus group. A potentially powerful approach to affecting behaviour change is to

surround individual people with social groups that normalise desired behaviours, and online spaces have shown the potential to foster the growth of social communities with a common interest in climate change [97]. Lee *et al.* also highlight having a publicly viewable profile as one of the features developed to create a community, supporting the need for user story *1.6* [97]. Based on the insights gained from the focus group, it was identified that the initial moments after downloading an app play a critical role. If users fail to grasp the app's purpose within the first few seconds, they are likely to uninstall it. To address this issue, user story *1.4* was developed to ensure a seamless onboarding experience and mitigate the risk of users abandoning the app. As stated in the focus group, finding a community that believes in the same things as oneself is motivating for participation in civic activities, justifying the need for user story *1.3*.

The need for user identification can also be connected to the third core motivator of the FBM, namely *Social acceptance / Rejection*. As Fogg outlines, the social technologies of today's society have made the methods for motivating users through social acceptance or rejection blossom [47]. However, the use of social media data in research raises some important ethical concerns, and the question of whether social media data should be considered public or private is one of the biggest concerns [98]. These questions should be concerned when developing the application, in order for the research to be considered ethical. The user stories for Goal 1 are shown in Table 6.1.

Goal	**User stories**
A new user should be able to register and add relevant personal information that will be shown on a publicly viewable profile	(1.1) As a User, I want to be able to register on the application, so that I can start using the application (1.2) As a User, I want to be able to log in and out, so that I can choose when I want to be active on the application (1.3) As a User, I want to be able to add information about an area of the city and personal interests, so that I can have a personalised experience (1.4) As a User, I want to be presented with easily understandable information before registering, so that I can learn more about the application and the problem (1.5) As a User, I want to be able to edit personal information, so that I have the option of making changes when I want to (1.6) As a User, I want to have a publicly viewable profile, so that I can be found by others and my public information can be seen by other users

Table 6.1: Table of application requirements Goal 1

Goal 2

Goal 2 is connected to Goal 1, but the user stories for this goal are more directly connected to the social interaction aspect of the application. There are several studies supporting the social aspect of promoting behaviour change and facilitating interaction with other people. Positive peer pressure may be a good strategy for the promotion of environmental behaviour change, and also drive behaviour change by increasing motivation through the wish for social acceptance [47]. Social liberation, namely opportunities to show that the community supports the target behaviour, is identified as one of ten processes of change in the TTM, to help people commit to a permanent change [46]. Specifically for this goal, Lee *et al.* highlight the feature of viewing other users' activity in a feed, and the ability to react and give positive feedback as features to promote discussion, sharing of knowledge and contribution [97]. These features give grounds for user stories *2.3*, *2.4* and *2.6.*, further justifying the formulated goal. The user stories for Goal 2 are shown in Table 6.2.

Goal	**User stories**
A user should be able to create a network to interact with other users	(2.1) As a User, I want to be able to add other users as friends and see the activity of friends, so that I can get motivated by others' activity (2.2) As a User, I want to get suggestions for users to add as friends, based on location and interests, so that I can create the best network for myself (2.3) As a User, I want to be able to create posts about different events and challenges, so that I can actively participate by sharing personal content (2.4) As a User, I want to be able to comment, show appreciation and like other users' posts, so that I can interact with my network (2.5) As a User, I want to be able to start different sustainable challenges and compete with my network, so that I can get motivated by the competition aspect (2.6) As a User, I want to be notified when a friend completes a challenge or participates in an event, so that I can be motivated by my friends' activity

Table 6.2: Table of application requirements Goal 2

Goal 3

The third goal regards the user's ability to make contributions towards a more sustainable city. As pointed out as one of the most important aspects of the CrAFt

project, the involvement of citizens will be decisive in making the cities of the future [8]. In addition, Magalhães *et al.* [37] state that the contributions of citizens can produce better social and environmental results, justifying this goal. The discussion in the focus group about the importance of understanding the effects of actions and feeling the difference you can make also supports this goal. Furthermore, the focus group participants' highlighting the social aspect as an important motivational factor for taking part in voluntary activities justify user stories *3.1* and *3.2*. According to Lee *et al.*, it is noted that simply gaining a better understanding of a wide-ranging issue does not automatically result in taking action. To address this, they suggest that offering practical and readily applicable information could be an effective strategy to motivate individuals to make sustainable changes in their lifestyles [97]. In light of this perspective, the incorporation of user story *3.3* is justified. Participant 3 in the focus group highlighting the importance of relatable information about the problem to understand how to contribute is also a justification for this user story. The user stories for Goal 3 are shown in Table 6.3.

Goal	**User stories**
A user should be able to make contributions for a more sustainable city	(3.1) As a User, I want to be able to create inclusive events, so that I can facilitate social meetings for climate-neutrality (3.2) As a User, I want to be able to participate in events created by others and invite friends, so that I can take part in what is happening in my city (3.3) As a User, I want to be able to get information on how to contribute to a more climate-neutral city, so that I can contribute more

Table 6.3: Table of application requirements Goal 3

Goal 4

Goal 4 concerns the competition element of the application, and that users should be able to see their score and rank among their friends. Implementing gamification as a method to motivate users was supported by both a paper from the SLR [69] and the focus group. User stories *4.1* and *4.2* leverage the motivational drive of Core Drive 2 in the Octalysis framework. In addition, user story *4.2* leverages Core Drive 5, while user story *4.3* is justified by Participant 5 in the focus group mentioning the motivational aspect of being able to track their own progress. The implemented game elements in relation to the core drives of Octalysis are further explained and justified in Section 6.2.2. The user stories for Goal 4 are shown in Table 6.4.

Goal	User stories
A user should be able to see their score and rank and compete with their friends	(4.1) As a User, I want to be awarded points and badges for completing challenges, and other positive actions, so that I can be awarded for desired behaviour and motivated to do more (4.2) As a User, I want to be able to see my own points in a leaderboard, so that I can compare myself to friends (4.3) As a User, I want to be able to track my own progress in a challenge, so that I can follow my progression towards finishing the challenge (4.4) As a User, I want to show my badges on my profile, and also see others badges on their profiles, so that I can show my achievements and also be motivated by others

Table 6.4: Table of application requirements Goal 4

Goal 5

The last goal concerns accessibility, to ensure the inclusion of all potential users of the app. As introduced in Chapter 2 an important part of reaching the climate goals is making sure that no one is left behind, and as our mobile application aims at environmental behaviour change for individuals, an important application requirement is making sure that the app is accessible so that all citizens have equal possibilities of contribution. Therefore, the development and design choices made must be done in an inclusive way, making sure the application can be equally understood and used by all people. The provided user stories outline some important points that should be followed when making a mobile application, guided by different sources[1][24]. Ballantyne *et al.* highlight the importance of mobile applications being usable by users with disabilities, especially because of the increased amount of mobile device users [23], and present universal guidelines to ensure the accessibility of mobile apps. In the further development of the application, we strongly suggest that such a framework is followed strictly to ensure inclusion for all users. Our design choices based on these user stories are presented in Section 6.2.4. The user stories for Goal 5 are shown in Table 6.5.

6.2 Developed Prototype

This section presents the developed prototype, outlining the main features of the prototype in Section 6.2.1, the gamification elements of the application in Section 6.2.2, the implemented features related to the TTM in Section 6.2.3, and the prototype design choices in Section 6.2.4. The prototype aims to accomplish

[1] `https://developer.apple.com/design/human-interface-guidelines/inclusion`

Goal	**User stories**
The design of the application should be inclusive, providing equal opportunities for all users	(5.1) As a User, I want to understand all features easily, so that I am able to use the application as everyone else (5.2) As a User, I want to be presented a plain language with an inclusive tone, so that I do not struggle with understanding anything (5.3) As a User, I want to be able to choose among different languages in the application, so that I can use my preferred language (5.4) As a User, I want to use an application following the WCAG, so that I can use the application even though I have a disability (5.5) As a User, I want to use an application portraying human diversity, so that I recognize others like myself within the application (5.6) As a User, I want to use an application without unnecessary references to specific genders, so that I feel welcome independent of my gender identity

Table 6.5: Table of application requirements Goal 5

the goals presented in Section 6.1, and has been used as a means to answer the research questions through the usability testing presented in Chapter 7.

As a result of the suggestion phase in the design and creation strategy, paper prototypes were made to get a first visualisation of what the actual product could look like. These paper prototypes are shown in Figure 6.1 Further, primitive digital wireframes outlining main features were made, and these are shown in Figure 6.2, Figure 6.3, Figure 6.4 and Figure 6.5.

6.2.1 Main Features

This section will outline the main features of the developed mobile application prototype. The features are based on the application requirements presented and justified in Section 6.1, aiming to support answering the research questions of the project.

First Page

The first page of the application (before signing in or registering) contains information about the different options of the application, and also the option to "learn more" before registering. This feature is strongly connected to Goal 1, and specifically user story *1.4* in the application requirements. This feature has the

Figure 6.1: Paper prototypes

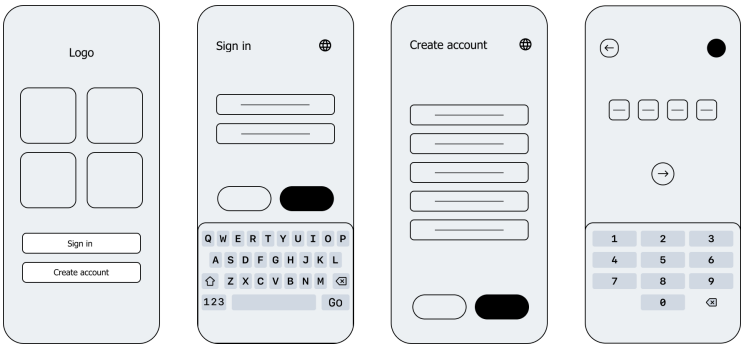

Figure 6.2: First page - wireframe

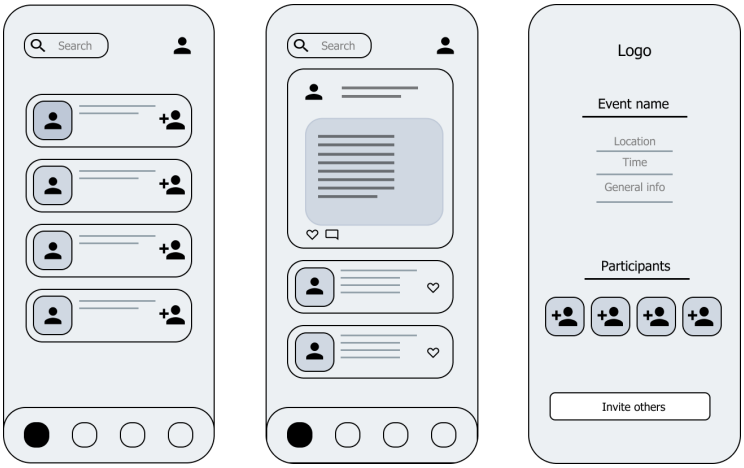

Figure 6.3: Network - wireframe

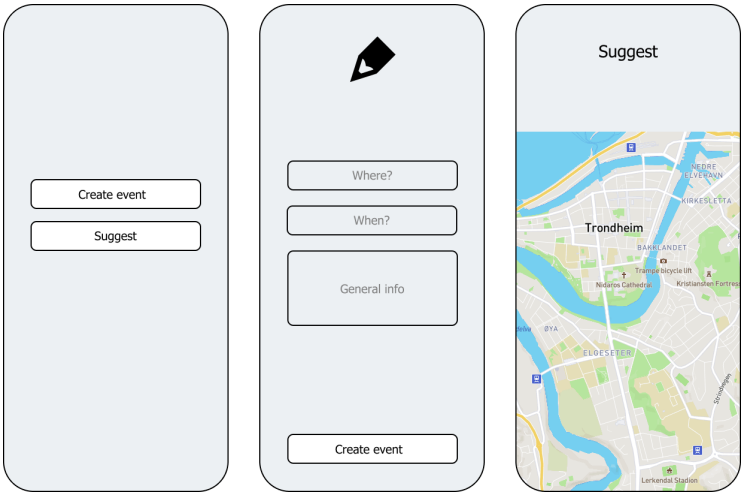

Figure 6.4: Create - wireframe

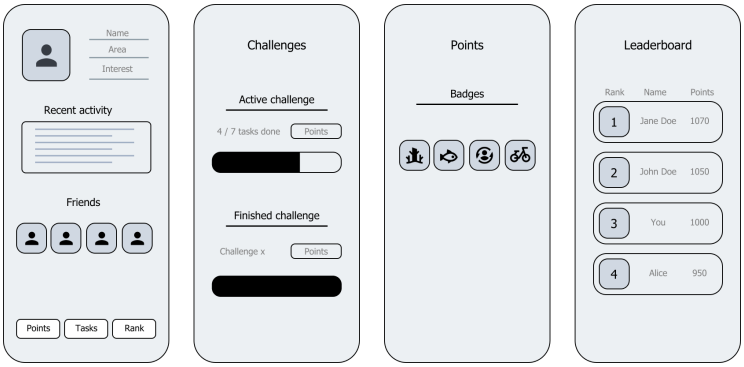

Figure 6.5: Challenges - wireframe

aim of showing the user the available options on the application and providing the opportunity to get information before registering as a user. These features are shown in Figure 6.6.

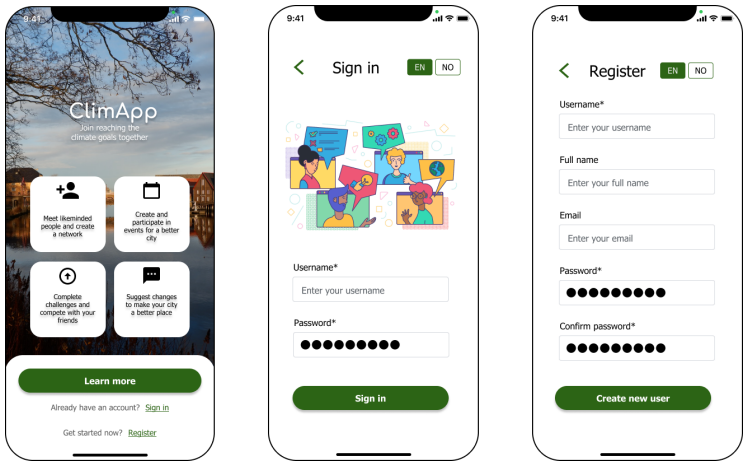

Figure 6.6: First page - Figma prototype

Profile

Each user has a personal profile page where they can see information about themselves, and also points and badges awarded. This feature is strongly connected to Goal 1, user story *1.6* in the application requirements. The users can also see their friends, namely those who are in their network. The profile page is shown in Figure 6.7.

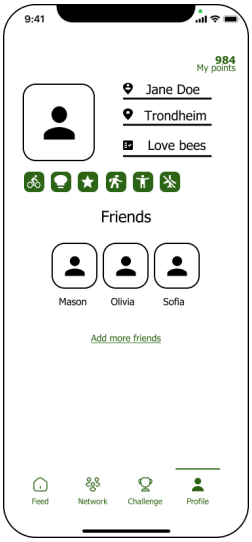

Figure 6.7: Profile - Figma prototype

Invite and Befriend

Adding other users as friends, and inviting friends to events are also important features of the application. This feature is strongly connected to user stories *2.1* and *3.2* in the application requirements. The ability to have a profile and be able to add other users as friends are core network aspects of the application. All the other aspects of the app, like participating in events and doing challenges, are connected to having a network of other users. These features are shown in Figure 6.8.

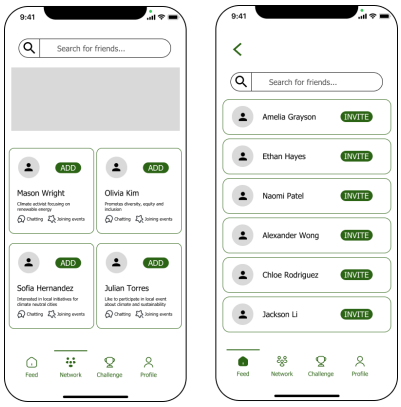

Figure 6.8: Invite and befriend - Figma prototype

Feed

The users of the application can see the activity of friends in a feed and are also able to react and comment on other users' posts or activities. This feature is strongly connected to Goal 2 in the application requirements. The feed is the first page the user sees after signing in or registering as a user on the application. The activities shown on the feed includes tips from other users on sustainable and inclusive behaviour, completion of challenges, and creation or joining of events. There is an own feed for events. These features are shown in Figure 6.9.

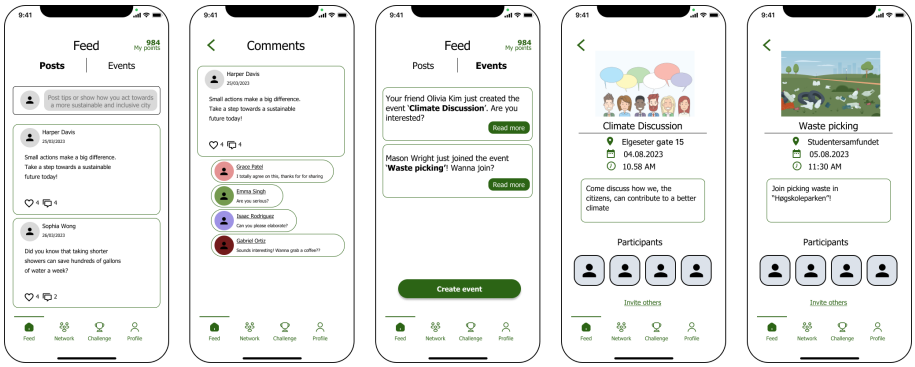

Figure 6.9: Feed - Figma prototype

Events

The concept of events is strongly connected to Goal 3 in the application requirements. As a user of the application, you are able to see nearby events, register for events and create your own events. Each user can also view different activities regarding events in their personal events feed, for instance if a friend has created an event or registered for one. When creating events the user has different options such as setting the name, description, location, time and inviting friends. The implemented *Create event* functionality is shown in Figure 6.10.

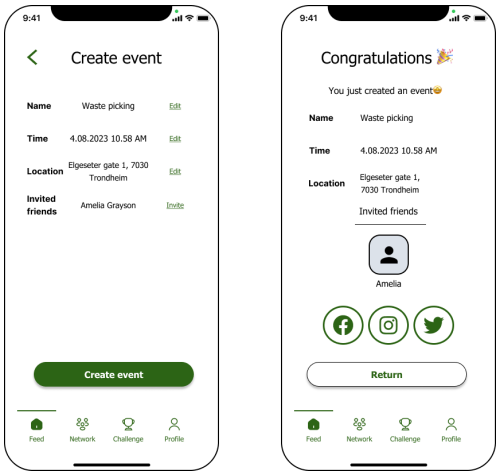

Figure 6.10: Events - Figma prototype

Challenges

The gamification elements of the application is mainly centred around the concept of challenges. This feature is strongly connected to Goal 4 in the application requirements. The challenges consist of one or several tasks, and the user can get points or badges for completing a challenge. A challenge can be a variety of different things, but the common denominator is that a challenge should help people do action to contribute to a more sustainable city. An example of a challenge can be to walk to work 5 days in a row or participate in 3 events in the upcoming weeks. The challenge-part of the prototype is shown in Figure 6.11.

6.2.2 App Gamification

As introduced in Chapter 2, gamification refers to the use of game design elements in non-game contexts [25], and this method prioritises human motivation over purely technical efficiency[2]. In our application, the Octalysis framework has been used to support the decision on which such elements should be implemented, as well as justification for the choices made.

[2] `https://yukaichou.com/gamification-examples/octalysis-complete-gamification-framework/`

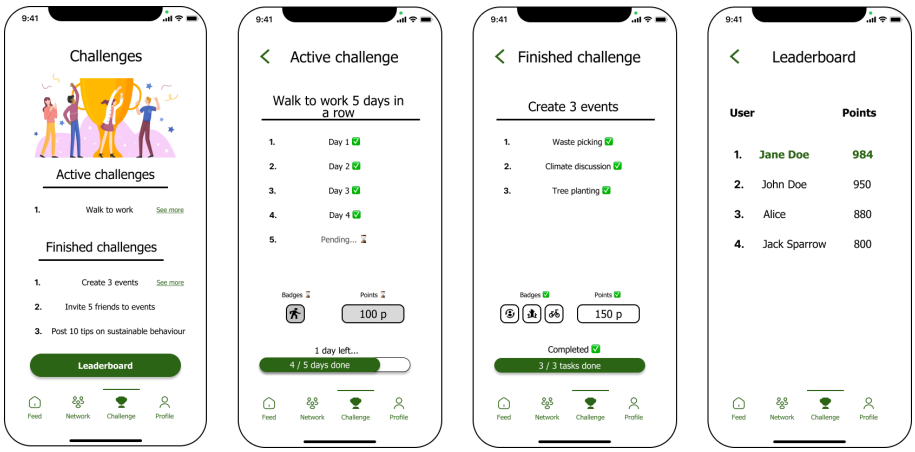

Figure 6.11: Challenges - Figma prototype

The implementation of core drives in the application is essential, as Chou defends that without any core drives present in an application with gamification as a main feature, there will be no motivation. With respect to our application, we have implemented several core drives. *1: Epic Meaning & Calling*, *2: Development & Accomplishment* and *5: Social influence and relatedness* are all the core drives considered in our application, and how they relate to the implemented game elements in our application are discussed below. However, our implemented gamification elements are not only based on Octalysis, but also on results from the focus group, outlining what gamification elements the participants found most motivating.

Core Drive 1 - Epic Meaning and Calling

Core Drive 1 is present when users perceive their activities as significant contributions to the community[3]. In our application, we believe that users will experience a sense of fulfilment and purpose by actively participating in challenges and attending events. By doing so, they can feel that their actions are making a meaningful impact on the environment and ultimately contributing to climate neutrality and inclusion in the city.

Core Drive 2 - Development and Accomplishment

This core drive fuels individuals' sense of pride and fulfilment[4]. In our application, we reward users with points for positive actions and badges for completing challenges. The leaderboard allows users to see their point totals compared to others. These features provide tangible measures of progress, skill development, and achievement, motivating users to actively engage and find direction in their

[3]Octalysis: footnote 2
[4]Octalysis: footnote 2

tasks. By incorporating these elements, we foster a sense of accomplishment and drive ongoing user engagement.

Core Drive 5 - Relationships and Social Influence

Core Drive 5 taps into our intrinsic motivation driven by social interactions and a sense of belonging[5]. In our application, we have implemented features that foster connections and positive social influence. By enabling users to share sustainable behaviour tips, adding and inviting friends, and incorporating a leaderboard for friendly competition, we create intrinsic motivators that go beyond external rewards. This approach ensures sustained user engagement, as multiple studies have shown that relying solely on extrinsic incentives often leads to a significant drop in motivation once those incentives are removed[6]. By leveraging this core, we cultivate a lively community that promotes intrinsic motivation and fosters a sense of belonging among users.

6.2.3 Features and Components Related to the TTM

To support behaviour change through the application, the TTM [44] has been used as a behaviour change model in this project, as explained in Chapter 2. In addition to proposing six stages of behaviour change, the model identifies 10 processes of change to understand *how* shifts in behaviour occur. In the attempt to motivate citizens to contribute to a sustainable and inclusive city, and change the environmental behaviour of citizens, the stages and processes of change have been used as a rationale for the features and components implemented, as seen in Table 6.6. Cellina *et al.* [99] have made a similar table, and we have followed the same approach to outline the application features connected to the steps and processes in the TTM.

[5]Octalysis: footnote 2
[6]Octalysis: footnote 2

Stages of Change	**Processes of Change**	**Our Application Features/ Components**
Precontemplation	*Consciousness Raising* Increase the awareness of a behaviour's causes, effects and cues	- Feed where the users can gain insight - Initial information about the problem before registering
Contemplation	*Self-Reevaluation* Cognitive and affective assessment of one's self-image, with and without a specific behaviour	- Success-stories from other users
Preparation	*Self-liberation* The belief that one can change and commitment to act on such a belief	- Registration for challenges
Action and Maintenance	*Helping Relationships* Social support, such as care, trust, openness, acceptance and general support, for new behaviour	- In-person events outside the application - Ability to show appreciation on other users' posts
	Social liberation Environmental opportunities that exist to show society is supportive of the healthy behaviour	- Community support through likes and comments on posts
	Reinforcment management Rewarding oneself or being rewarded by others for making changes	- Points - Badges
	Counterconditioning Substituting sustainable behaviours and thoughts for unsustainable behaviours and thoughts	- Challenges - Reading other users' tips on sustainable behaviour

Table 6.6: Features and components of our application, with respect to stages and processes of change defined by the TTM [44]

6.2.4 Design Choices

This section specifies the design choices made when developing the prototype, which also should be taken into account when continuing the development of the application. The choices were guided by the developed application requirements presented earlier in this chapter, specifically under Goal 5.

In general, we used the 6 Principles of Design by Norman[7] to guide our application design. Our main design objective is that the mobile application prototype

[7] `https://www.educative.io/answers/what-are-normans-design-principles`

should work properly, be simple to use, and be intuitive for all users, as well as accessible for all users.

Fonts

We have chosen to use Verdana as our font type, as it is considered one of the most accessible fonts[8], and also was consistent with the overall design of the application. We also focused on using plain language, to make the application understandable for everyone.

Colours

When we decided on the colour theme for the application, we both focused on choosing colours matching the theme of the application, and colours meeting the colour contrast requirements of WCAG conformance level AAA. We used a Figma plugin[9] to assess our colours and make sure they met the requirements of colour contrast. To match the objective of the application, we chose to use a variant of green (#2C6415) as our main colour for elements, in addition to black text and white background to assure the required contrasts.

Icons

Avoidance of references to specific genders in an application helps everyone feel welcome[10], and in contexts where there is a need for demographic identifiers such as gender, inclusive alternatives should be provided to the user [24]. When it comes to registering for the application, we chose not to include gender as an option, because we do not think it is necessary at this stage of the design to meet the objective of the application. The use of a nongendered human image wherever it is required to portray a generic person or people reaffirms the idea that a generic person refers to a human, not a man or a woman[11]. The icons we used in the prototype were therefore completely generic and nongendered.

Images

For our images, we have used Colourbox[12], as NTNU has a subscription to this Danish image bank. One of the most obvious ways an app can make everyone feel welcome is by portraying human diversity because people are less likely to feel excluded from an app and its accompanying contents when they see other people

[8] https://www.siteimprove.com/glossary/accessible-fonts/

[9] https://www.figma.com/community/plugin/733159460536249875/A11y---Color-Contrast-Checker

[10] https://developer.apple.com/design/human-interface-guidelines/inclusion

[11] Apple Developer: footnote 10

[12] https://www.colourbox.dk/

who are similar to themselves there[13]. We have therefore chosen images with the aim to portray a range of human characteristics, such as gender and race.

6.3 Prototype Changes Between Iterations

Several design changes were made to the prototype based on the feedback from Iteration 1 and before Iteration 2 of usability testing. Many minor design changes were made, but this section will highlight the most important changes. The main focus of the changes was to make the application easier to use and to highlight the most important concepts in a better and more understandable way.

Adding of Tab Names

One of the most obvious changes was to make the tabs more visible by adding text under each of the icons, as many of the participants in Iteration 1 of the usability testing uttered a struggle to understand what the different icons represented. The names were chosen with the aim of describing as precisely as possible what to find under each tab, and the names are *Feed*, *Network*, *Challenges* and *Profile*.

Highlighting the Concept of Challenges

We also decided to move *Challenges* to its own tab, to make it more understandable and to highlight this concept to a greater extent. We also implemented some additional gamification design changes, such as making badges clickable and providing information upon clicking to enhance their understanding. Additionally, we emphasized the *My Points* feature on the user profile and in the feed to serve as a reminder of current points and motivate users to strive for more.

Introduction of Tutorial

Some users expressed a wish for more information about the app before registering, and therefore we added a tutorial to highlight the most important features of the app as a voluntary alternative for users who want to *Learn more* before registering.

Removal of *Suggest Action*

The first version of the prototype gave the users the option of suggesting an action for a more sustainable city. For Iteration 2, we decided to remove this feature for several reasons. Some users struggled to separate the concepts of *Events* and *Suggestion*, and none of the users highlighted this feature as a motivational factor for using the application. Therefore it seemed like a good choice to remove this feature to distinguish more between the most important features, and not make the

[13]Apple Developer: footnote 10

application overwhelming and difficult to understand. A third reason for removing this feature was that the suggestions from the users must be handled by someone, for instance the municipality, and this connection has not been established at this stage of the development.

6.4 Proposed Technology Stack

In this section, we present a proposal for the technology stack that can be used for the development of our mobile application prototype. It is important to note that this proposal represents one possible approach and that there are alternative ways to implement the application. Our proposed technology stack is based on careful consideration of the project requirements, desired functionalities, and development efficiency, as well as aiming to provide a relatively easy way to implement the application in a short amount of time. The following technologies have been selected, each serving a specific purpose, to provide a robust and scalable solution.

Frontend

We propose utilising React Native[14] as the frontend development framework for the application. React Native is a renowned cross-platform JavaScript framework that offers efficiency and code reusability. It enables the creation of a single codebase that can be deployed on both iOS and Android platforms. Using React Native, the entire frontend can be written in JavaScript, which is widely used and recognised as the most popular programming language among developers as of 2022[15]. This choice not only saves development time and effort but also grants access to a vast and supportive community. JavaScript's popularity ensures the availability of extensive resources, libraries, and frameworks that can be harnessed to enhance the development process and overcome any challenges that may arise. A possible alternative to coding in JavaScript is to use TypeScript[16], which is a superset of JavaScript with type definitions, meaning that it adds rules about how different kinds of values can be used, which can make the code more readable and easier to maintain.

Backend and Database

We propose utilising Firebase[17] as the backend and database solution for several compelling reasons. Firebase is a comprehensive suite of cloud-based services that offer numerous benefits. Firstly, it provides a serverless backend infrastructure, eliminating the need for a separate backend server and streamlining the development process. Additionally, Firebase seamlessly integrates with React Native

[14] https://reactnative.dev/
[15] https://www.statista.com/statistics/793628/worldwide-developer-survey-most-used-languages/
[16] https://www.typescriptlang.org/
[17] https://firebase.google.com/

through its dedicated JavaScript Software Development Kit (SDK) designed for React Native applications. This integration allows for efficient development and takes advantage of React Native's capabilities. Moreover, Firebase offers real-time data synchronization, enabling the storage and synchronization of the user profiles, network relationships, event details, challenges, and other data in real-time across multiple devices. This ensures a smooth and responsive user experience. Overall, Firebase serves as an advantageous backend and database solution due to its serverless architecture, React Native integration, and real-time data synchronisation capabilities.

Alternative Technologies

While the proposed combination of React Native and Firebase serves as a viable solution for initiating the development of the mobile application, it is worth mentioning the alternative possibility of incorporating MongoDB[18] and Node.js[19] for the database and backend respectively. MongoDB's flexibility and scalability make it a suitable choice for accommodating dynamic data relationships and growing user interactions. Neo4j[20], a graph database, presents another database option. With its graph-based structure, Neo4j is well-suited for managing social network aspects such as friend networks and relationships. It offers efficient retrieval of interconnected data and can enhance the user experience through graph querying and recommendation algorithms. As the application evolves, Neo4j can provide a robust and efficient solution for handling the growing complexity of the data model. Although these alternatives present a compelling option, we suggest starting with React Native and Firebase to leverage their efficiency and cross-platform capabilities. However, with the possibility of the growing complexity of the application and expansion in the user base in the future, it may become necessary to consider integrating MongoDB, Neo4j and Node.js to ensure optimal scalability and address the evolving data requirements. An alternative to React Native for frontend development is Flutter[21]. Flutter is also a cross-platform framework that can be considered as a promising alternative for this purpose.

6.5 Similar Solutions

We have found some similar solutions, both in the SLR presented in Chapter 3, and by searching directly for similar solutions on the Internet. In general, these solutions have some similarities to the proposed solution, but to the best of our knowledge, there is no such solution available as the one we are proposing, namely a mobile application using gamification and network aspects to facilitate environmental behaviour change for individuals in cities.

[18] `https://www.mongodb.com/`
[19] `https://nodejs.org/en`
[20] `https://neo4j.com/`
[21] `https://flutter.dev/`

Both Ferron *et al.* [65], Luger-Bazinger and Hornung-Prähauser [67], and Cellina *et al.* [99] focuses on sustainable behaviour change with the use of gamification for more sustainable mobility. Specifically, Ferron *et al.* developed a game using gamification to encourage a positive behaviour change in mobility behaviour, concluding that players enjoyed using the game and reported a change in behaviour for more sustainable mobility habits [65]. Luger-Bazinger and Hornung-Prähauser present a personal mobility app that uses gamification and nudging to make citizens make more sustainable mobility choices [67]. Cellina *et al.* present "GoEco!", a mobile application utilising eco-feedback, social comparison, autonomous mobility tracking, and gamification aspects to influence individual modality change [99], developed based on the TTM [44]. Those three solutions are similar to our solution in the way that they focus on individual sustainable behaviour change with the use of a mobile application and gamification, but differ in their focus on sustainable mobility. We have also found existing applications when searching the web. "We don't Have Time"[22] is a social media for climate solutions, and this web platform works as a climate dialogue with the aim of influencing businesses and world leaders to act on the climate crisis. "Klima"[23] is a climate app to help people turn carbon neutral in an immediate and sustainable way, by calculating their carbon footprint, getting tips on how to live more sustainably and helping inspire friends to do the same. Another mobile app solution for citizen awareness about personal carbon footprint is Smiling Earth [43]. This application provides the user with feedback on their actions and the consequences of their actions by visualisation of daily activities and CO2 emissions, with the objective to motivate behaviour change. "EcoSocial"[24] is an environmental mobile application for people to connect with others, collaborate and make positive environmental change. Therefore, these applications have similarities to our solution, but the focus on using gamification elements as a main driver for behaviour change in our solution separates them from our application.

[22] https://app.wedonthavetime.org/
[23] https://klima.com/
[24] https://ecosocial.co/

Chapter 7

Usability Testing

Usability testing is a popular research methodology in UX. As stated by Moran, a facilitator asks a participant to perform tasks, usually using one or more specific user interfaces. The researcher then watches the behaviour of the participants and listens to feedback as they complete each task of the test [81]. To evaluate and receive user feedback on the developed mobile application prototype, we conducted a total of 14 usability tests over 2 iterations, each test lasting approximately 30 minutes. The methodology followed is described in detail in Section 4.2.4. This chapter presents the obtained results from the two iterations of usability testing.

7.1 Results

The following section presents the findings from the two iterations of usability testing, organised to address the research questions formulated for our research. We begin by presenting the results associated with RQ1 in Section 7.1.1, followed by a presentation of the results related to RQ2 in Section 7.1.2. These findings are derived from a thorough examination of both qualitative and quantitative data, supplemented by valuable insights gained from observations made during the two iterations of our study. Together, these results provide a comprehensive understanding of the research questions and offer valuable insights into the investigated phenomenon. Lastly, the tables showing all the results from the thematic data analysis are presented, organised by participant and iteration.

7.1.1 RQ1: How Should a Digital Platform Be Designed to Motivate Citizens to Contribute to a Sustainable and Inclusive City?

For this research question, results emerged both on motivational factors for individuals' contribution to a sustainable and inclusive city and also more specifically on how the system should be designed. In addition, the scores from the SUS questionnaire will be presented under this research question, as the usability of the prototype will give insights into perceptions of the design, and guide further design implementations in the application.

Motivational Factors

In Iteration 1, several participants highlighted that a motivational factor for using the application was the ability to network and interact with other users. Participant 6 mentioned that seeing others doing something productive would likely help the motivation to change behaviour, and Participant 2 pointed out that with the interaction with other users, it was possible to motivate each other in the application. Participant 1 stated that the networking part of the prototype was beneficial as it helped the participant connect to a group of people committing to the same goal, again highlighting the importance of networking in the prototype. Participant 5 recommended some features that could be implemented to improve the networking and interaction with others in the application. One of the suggestions was the ability to see who used the application nearby, so users could interact with other users located nearby and consequently make a stronger community. The participant also suggested a section of the application where it was possible to explore what other users, not only friends, were posting and doing to act sustainable, and by this get inspired.

The participants in the first iteration also highlighted the motivational aspect of finding a community that believes in the same things. Participant 2 would much rather participate in civic activities together with others in the same community than alone. Participant 3 mentioned that the community could offer information about different sustainable events, making them easier to join. Another participant that highlighted the importance of information in the application was Participant 7, who suggested a section where the context of the application is presented, in the form of a blog. Furthermore, Participant 7 also suggested the addition of a feature that includes news related to initiatives and consequences on the topic. The need for some additional information in the application was also surfacing in Iteration 2, where Participant 4 expressed a desire for additional information on how to contribute to the cause on a personal level. This participant highlighted that such information would not only facilitate their contribution but also make it more relatable.

In Iteration 2, the participants agreed with the participants in Iteration 1 on the motivational factor that networking and interaction with other users possessed. Participant 7 stated that the aspect of having friends on the application, and knowing that related people also use the application, is motivating. Participant 6 would be motivated to continue to use the application, but with the precaution that others also used it. Participant 4 reported thinking that the app could have helped in becoming more motivated, as it facilitated finding activities that could be done together with others. Additionally, Participant 4 mentioned a higher threshold for contributing to the cause alone compared to doing it with others. Seeing others do something positive can be motivational, as reported by several participants in Iteration 1. This was also reported by Participant 6 in Iteration 2, using the mobile application Hold[1] as an example. The application rewards users for not using

[1] https://www.hold.app/

their phones during study sessions, and the participant found it motivating to see friends also abstaining from phone use, comparing this to the posts in the feed in our prototype. Participant 5 in Iteration 2 agreed with Participant 5 in Iteration 1 about the motivational aspect of connecting to people close by, and suggested a feature where users could connect with people in the same housing association as themselves. The participant also had a new view on the comparison to others within the application. The participant mentioned that it is motivating when others can see that one is doing a good job, using the application Hold as an example.

Although receiving feedback that the prototype had features supporting networking and interaction with other users, some of the participants in Iteration 1 suggested features that could further enhance the networking and interaction, thus increasing the likelihood of a user being motivated to use the application. Participant 4 agreed that utilising the application would enhance the motivation to engage in sustainable actions. However, the participant suggested that incorporating a messaging feature would further boost motivation. Specifically, the participant proposed that a chat function could be employed to notify friends when surpassing them in terms of points. Participant 5 would also like to see a chat feature where it is possible to interact with other users.

The results from both iterations underscored the significance of networking and interaction with others within the application as motivational factors. However, in the second iteration, some scepticism regarding the motivational effect of networking surfaced among the participants. Participant 3 explicitly stated that the networking aspect alone would not be sufficient to motivate to the use of the application, expressing the need for additional incentives. Similarly, Participant 5 exhibited doubt regarding the effectiveness of the networking component for motivation. Additionally, Participant 1 did not envision an environment where the participant's group of friends would provide mutual encouragement for challenges, emphasizing that the network of friends would not contribute to the participant's motivation. These insights shed light on the potential limitations of relying solely on networking as a motivational strategy and highlight the importance of incorporating other motivating factors and incentives within the application.

Throughout the usability testing, the participants provided feedback both on the idea and objective of the app. In Iteration 1, Participant 4 stated that the idea of the application was very good and expressed a desire to use the system frequently. Participant 7 highlighted the importance and need for such an application, also expressing that the theme was very interesting. Participant 1 expressed a belief in these kinds of applications, while Participant 5 stated a liking for social projects like this. On the other hand, some of the participants in Iteration 2 were more sceptical of the use of applications like these, expressing a lack of interest in the use. For instance, Participant 4 expressed a general disinterest in similar applications. Participant 7, although acknowledging the motivating factors of the leaderboard, competition, and the social aspect with friends, did not express a strong inclination to use the application. Similarly, Participant 3 indicated a lower likelihood to use the application frequently, while Participant 5 expressed uncer-

tainty regarding personal motivation to use the application.

Design Feedback

During Iteration 1, the participants suggested several improvements to the design of the prototype. Some of the concepts in the prototype were difficult for the participants to understand. What emerged, among other things, was that participants had trouble understanding the relation between creating an event, and suggesting an action. Participant 4 mentioned that it was not clear if the events and suggestions of actions were separate or integrated concepts, while Participant 7 thought the concept of suggesting an action was confusing, and recommended separating the concepts of "suggest action" and "create event". Participant 6 also shared the same recommendation. Participant 1 mentioned that it was not easy to realise where to suggest an action.

Another conceptual issue the participant struggled to understand was the concept of challenges. Participant 4 stated that it was not clear that a challenge consisted of several tasks, and Participant 1 agreed that the concept of challenge needed to be clearer for the user. Badges are strongly related to challenges, as users earn badges when finishing a challenge, and some participants found this concept hard to grasp. Participant 5 thought the icons for badges were clickable, and did not understand what they meant, and Participant 1 meant that by making the challenge concept more clear to the users, the concept of badges would be easier to understand.

Several participants in Iteration 1 also suggested improvements for the navigation bar, to make it easier to understand. The meaning behind some of the icons was not intuitive for the participants, especially the icon for creating an action. Participants 5 and 7 mentioned that an icon of a plus sign could be a better choice, and mentioned that this was a heavily used icon representing a "create" action in Brazil. Besides changing the icon, several of the participants also recommended naming the icons in order to ease the users' navigation in the navigation bar.

The action of creating events also caused some problems for the participants in both iterations. In Iteration 1, as the button with "Create event" was visible before filling in the necessary information to create the event, some participants tried creating the event, and got feedback that all fields had to be filled. Participant 2 recommended a form where the user filled in all of the information at the same time, stating that it would be more intuitive. Participants 3 and 7 agreed with this, as it would make it easier for the user to edit each section whenever they wanted. Although the majority of the participants had some problems with the creation of events, Participant 6 stated that the process was easy. After implementing Participant 2's suggestion of a form, none of the participants in Iteration 2 expressed concerns with the creation of events, but other concerns related to the concept of events surfaced. When navigating back to the event section of the application after completing Activity 2, Participant 4 expressed finding it challenging to locate the option for creating an event. Participant 2 also had some problems when nav-

igating back, and suggested a dedicated "Create event" tab, and used platforms like Instagram as an example of where this is done successfully. Participant 7 suggested that newly created events should appear in the feed and expressed a desire for events to be displayed on the user's own profile.

In Iteration 2, concerning the popup information boxes implemented for user feedback when inviting and adding friends, Participant 3 noted that the pop-up box disappeared too quickly, leaving little time to read the feedback. This observation was further supported by Participant 4, who pointed out that the pop-up only appeared for a brief one-second duration. This issue was also noted by the observer, as Participant 4 and Participant 5 attempted to click the close button on the pop-up box but were unable to do so before it vanished.

It is worth noting that, in comparison to the first iteration of usability testing, the number of design improvement suggestions was relatively lower. This indicates that the second iteration addressed several of the concerns raised by participants, resulting in a more refined design. However, the feedback received regarding the event section and pop-up notifications provides valuable insights for further enhancing the user experience.

Observations

This section presents the observations made by the researchers during both usability testing sessions. These observations played a crucial role in evaluating and refining the design of the prototype. By carefully examining the participants' interactions with the prototype, the researchers gained valuable insights into its usability, functionality, and overall user experience.

In general, most of the participants in Iteration 1 had few difficulties navigating the application, and when they were unsure about what to do, they managed to find out about it quite quickly. It was not observed many issues regarding the Figma prototype, as the interactivity implemented makes it feel almost like a fully developed application. There are however some drawbacks with this kind of prototype, such as the inability to fill out forms, but this was something each participant eventually understood and they managed to adapt well to this shortcoming. Although most of the participants managed to navigate the application without large problems, we observed some common uncertainties the participants had while navigating the application. We observed that many of the participants struggled to understand what the tab icons were meaning, leading to uncertainty about what the participant expected to find under each tab. Another observation was that some of the buttons, for instance "Read more" in the "Events" area, were hard to click. The user understood that it was a button and that it was clickable, but sometimes struggled to hit the button when trying to click it. The progress bar showing how much of a challenge the user has completed also mislead some participants to think it was a button, so some of them tried to click this unclickable element. Several participants also struggled to understand where to suggest an action during Task 5, so it did not seem intuitive to place this under the "Create"

tab. All these observations, combined with the oral feedback given by the participants, was taken into account when implementing the changes for Iteration 2, presented in Section 6.3.

As mentioned in Section 4.2.4, the second iteration of usability testing was done in a UX laboratory, giving us more data to observe how the participants interacted with the solution, and better prerequisites for more detailed observations. The changes based on the feedback from Iteration 1 generally seemed to remove some of the biggest usability issues observed in Iteration 1. Adding text under each tab icon removed the problem of participants not understanding the icons, causing issues in Iteration 1. Moving *challenges* away from the profile, and moving it to a separate tab, also seemed to make this concept easier to understand for the participants, as the participants in Iteration 2 had fewer issues with the tasks regarding this. The suggestion from Iteration 1 of adding a *tutorial*, or at least more information about the application, before signing up was implemented, but none of the participants exploited this part of the application. The concept of *suggesting actions* was also removed from the application, aiming to make the app easier to navigate and to highlight the features leading to higher motivation for the participants, such as events and challenges, and the observations from Iteration 2 underpins that the concepts of challenges and events were easier to understand after those design changes. Especially moving *Create event* to the *Events* feed, and making *Challenges* its own tab, seemed logical for the participants. Some participants missed the "Read more" buttons on a specific event, so they were increased in size. This issue did not occur in this round of tests, but some of the participants tried to click the entire *Event post*, an unclickable rectangle with information and the clickable "Read more" button inside it.

As in Iteration 1, most of the participants had few difficulties navigating the application, and if they were unsure what to do, they managed to find out about it quickly. One of the new observations we did was that many of the participants attempted to click unclickable elements. Some of these cases are related to the prototype not being entirely interactive, but also some non-interactive elements seemed clickable to some participants. Especially the *info-boxes* on the first page before logging in caught the attention of many of the participants, and some of them were unsure about whether these were possible to click or not. Another observation was that the participants were mishitting buttons. They correctly recognized that the elements were clickable, but they used several attempts to hit the actual element. Most of the participants one or several times during the tests missed the *back* arrow in the top left corner, hitting it only on the second or third attempt. The *register* and *invite* buttons were also missed by some participants.

System Usability

The following section presents the results obtained from the SUS, in both iterations. Both average scores and individual scores for each question will be presented, and figures are used to visualise the results against different benchmarks.

The average SUS scores per participant in Iteration 1 are shown in Figure 7.1. The average score for all participants in this iteration is *80.7*. Having found the margin of error to be 15.8, the 95% confidence interval is 64.9 to 96.5. The average score is between *Good* (71,4) and *Excellent* (85.5) according to Bangor *et al.* [94], without concerning the confidence interval.

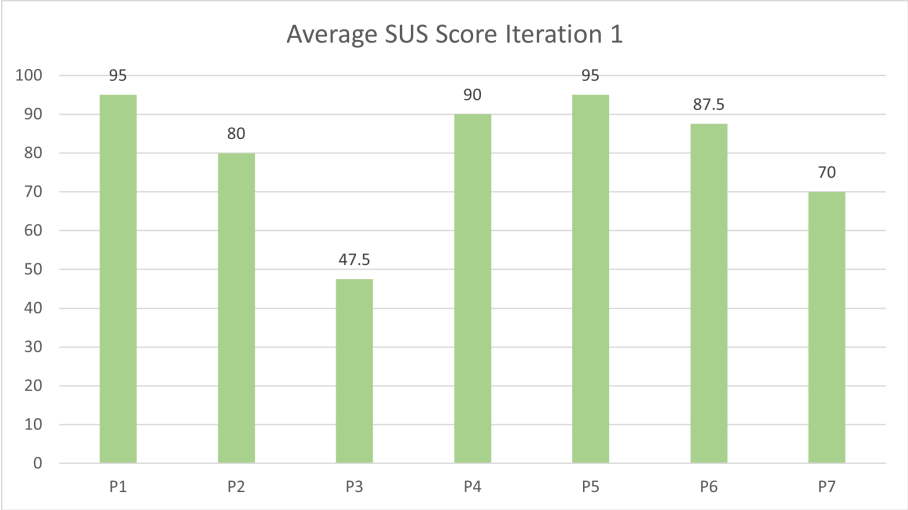

Figure 7.1: Average SUS score per participant in Iteration 1

Figure 7.2 shows the average score of the single questions, compared to the benchmark scores needed to gain an average total SUS score [100]. The scores for the single questions have been rebased to a 0 to 4 scale, by both subtracting 1 from the individual scores for all odd-numbered questions, in addition to subtracting all scores from the even-numbered questions from 5. Figure 7.3 shows the average score of the single questions, compared to the benchmark scores needed to gain an above-average total SUS score [100].

The average SUS scores per participant in Iteration 2 are shown in Figure 7.4. The average score for all participants in this iteration is *86.1*. The margin of error was found to be 4.0, thus indicating that the 95% confidence interval is 82.1 to 90.1. The average score is between *Excellent* (85.5) and *Best imaginable* (90.9) according to the mappings of SUS scores to adjectives of Bangor *et al.* [94], without concerning the confidence interval.

Figure 7.5 shows the average score of the individual questions, compared to the benchmark scores needed to obtain an average total SUS score of 68 [100]. The scores for the single questions have been rebased to a 0 to 4 scale, following the same approach as in Iteration 1. Figure 7.6 shows the average score of the individual questions, compared to the benchmark scores needed to obtain an above-average total SUS score of 80 [100]. Most of the average scores per question are above the benchmarks. Question 1 is under the benchmark for the average score, while Question 9 is similar to the benchmark to obtain the average score.

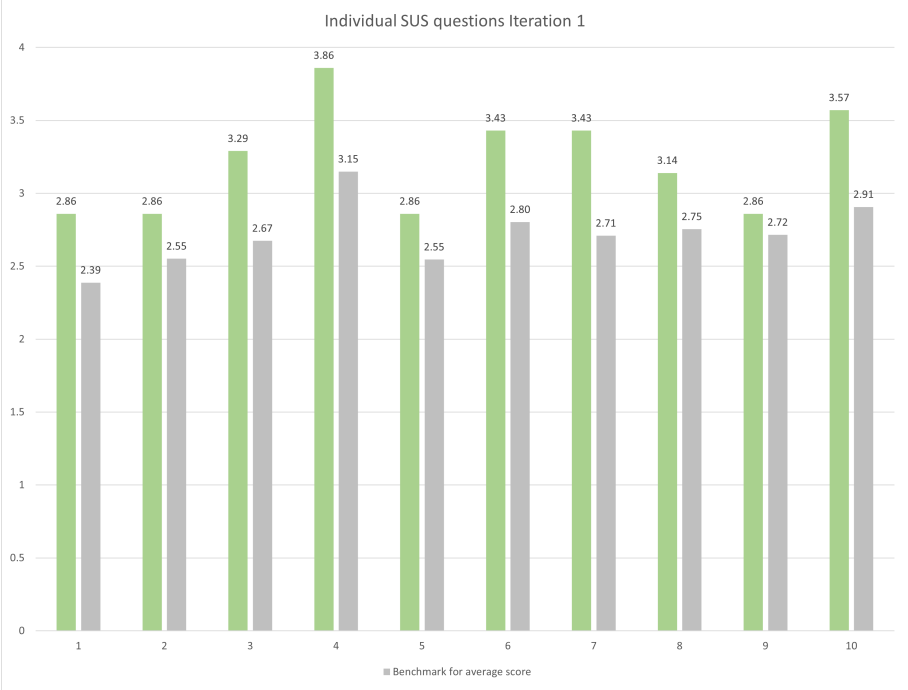

Figure 7.2: SUS scores per question compared to the benchmark to gain a total average SUS score in Iteration 1

7.1.2 RQ2: Which Specific Gamification Elements Should Be Implemented in Such a Digital Platform to Make Citizens Change Environmental Behaviour?

During both iterations, the participants provided feedback on the implemented gamification elements and provided some general thoughts on their relation with gamification and behaviour change. These results are mainly obtained from the interview questions asked at the end of each usability test, and not observations and feedback from the scenario and tasks.

In Iteration 1, what emerged was the participants' enthusiasm for competition elements to motivate users. Participant 4 mentioned finding motivation through competition and highlighted the use of points in the prototype as a great motivational feature. Participant 5 agreed that the points in the application were motivating, but highlighted that the points should be more visible as this would lead to more competition between users, possibly leading to the desired behaviour change. Participant 1 was fond of the challenge feature in the application, but meant that this concept should be put in the spotlight of the application. Implementing competitions or challenges between cities was a suggestion from Participant 5, again highlighting the motivational aspect of competition and challenges. Strongly related to the challenges are badges. Participant 7 stated that badges were motivating, Participant 4 emphasized the enjoyable aspect of collect-

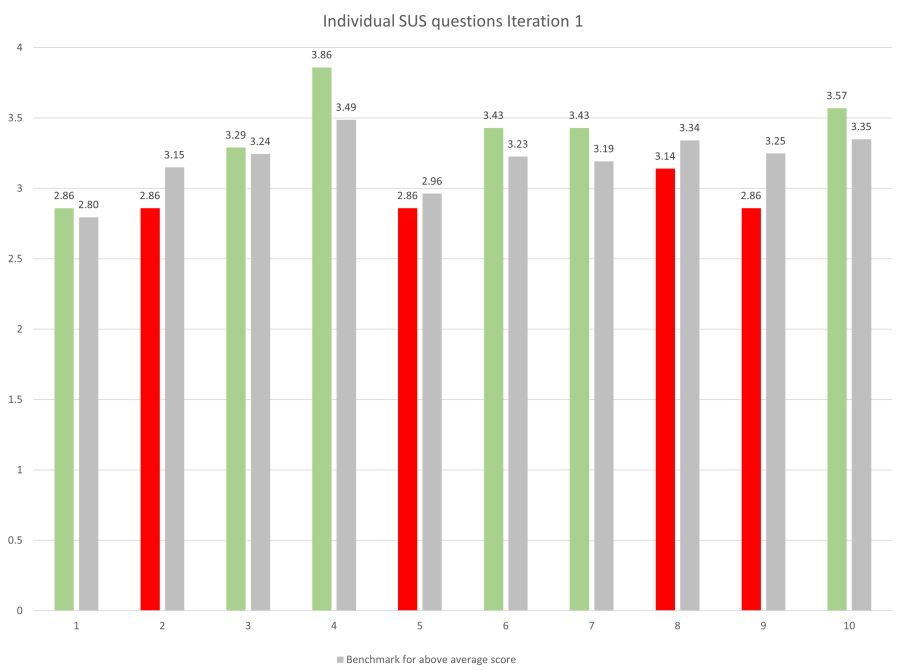

Figure 7.3: SUS scores per question compared to the benchmark to gain a total above average SUS score in Iteration 1

ing badges alongside friends within the application. Participant 4 also proposed the idea of sharing each obtained badge on one's social network, thus promoting the application and spreading awareness among a wider audience. Participant 5 expressed confusion regarding the meaning of the badges displayed on the profile, as they were presented without any additional explanation. Participant 3 disagreed with the other participants stating that the challenges and competitional aspect were motivating, and stated that the challenge part of the proposed solution was not that interesting when having a busy schedule.

When concerning gamification elements, Participant 1 warned about some unwanted side effects in the use of these elements. The participant had previous experience in design of gamification elements within digital systems and warned that users could be stressed out if they are pushed to gain badges and points and feel that they are not succeeding if they fail with gaining them. The language learning application Duolingo[2], where points and badges are rewarded when finishing different language tasks in the application, was used as an example. According to this participant, the gamification of Duolingo works because the users want to learn a new language, and gamification is just the means to continue pushing the user to learn the language.

In Iteration 2, the significance of challenges and competitions as strong motivators for using the application was once again emphasized by the participants.

[2]`https://www.duolingo.com/`

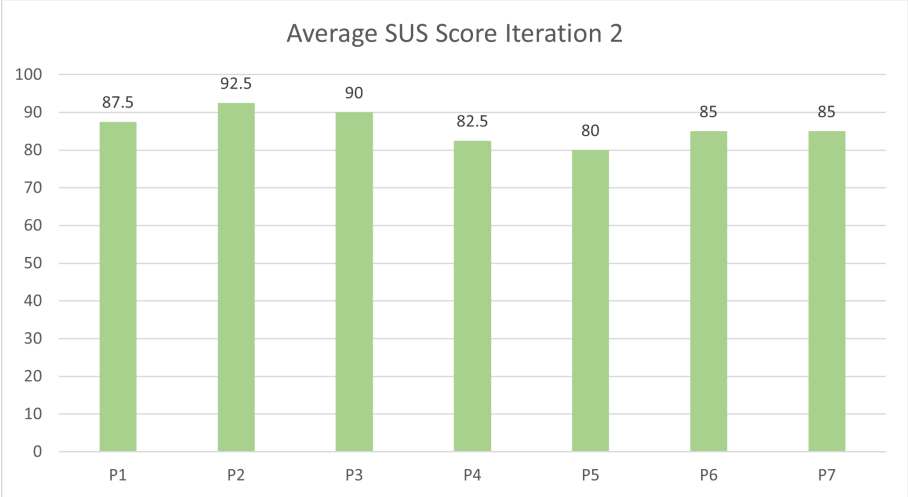

Figure 7.4: Average SUS score per participant in Iteration 2

Participant 7 shared the crucial role of competition in motivation, referencing numerous competitions with friends on other applications. Participant 5 highlighted the motivating aspect of challenges, recognizing that self-challenge offered a fresh perspective. Moreover, the concept of one-on-one challenges among users emerged as a notable feature. Participant 2 emphasized that head-to-head competitions would deepen user investment in the application. The integration of leaderboards, closely linked to challenges and competition, also emerged as a motivating factor. Participant 7 believed that leaderboards provided motivation, while Participant 2 enjoyed comparing performance with other users and suggested the implementation of a comprehensive leaderboard not only including friends. Additionally, Participant 7 recommended incorporating challenges that users typically do not engage in independently, thereby necessitating the application's involvement to complete those challenges. Regarding the effect of badges on motivation, views varied among the participants. Participant 5 acknowledged that badges can serve as a motivational factor, while Participant 7 expressed scepticism about the impact badges would have on motivation. These findings collectively underscore the importance of challenges, competition, and leaderboards as key drivers of user engagement and motivation, while also highlighting the diverse perspectives on the motivational influence of badges.

While Iteration 1 highlighted the motivational aspect of the points system within the prototype, feedback from participants in Iteration 2 indicated that points alone were not a strong driver of motivation. Participants 1, 3, and 6 mentioned that points would be more motivating if they could be redeemed for external rewards, drawing on their experiences with the Hold application as an example. Furthermore, Participant 4 introduced a new perspective, stating that comparing points with friends added an element of fun, whereas comparing them against random users did not yield the same effect. Another noteworthy gamifica-

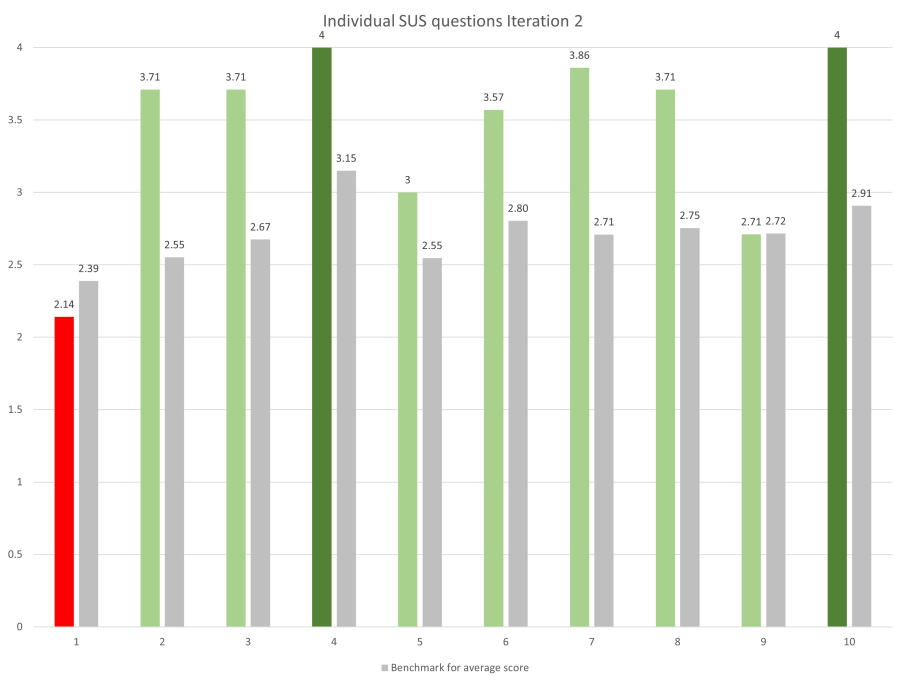

Figure 7.5: SUS scores per question compared to the benchmark to gain a total average SUS score in Iteration 2

tion element that emerged in this iteration was the concept of streaks. Participant 1 expressed that the motivation to use the application would be enhanced by achieving a streak of consecutive daily usage.

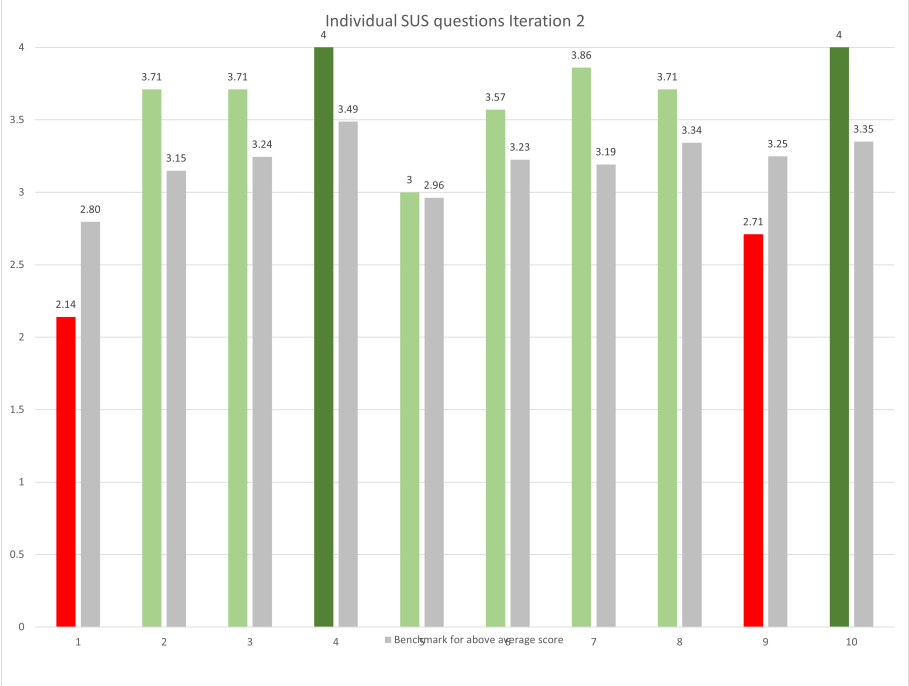

Figure 7.6: SUS scores per question compared to the benchmark to gain a total above average SUS score in Iteration 2

Data segment	**Themes**
"*But I wonder what is the grey circle? At first I thought that maybe I have to select and I was going to show that I had selected something*"	- Design features
"*And so when I am at the event I have to read more. I have to go and open about the event to be able to invite people. You're just fine here*"	- Design features
"*Go to the create tab and create an event. Create tab, create an event. And choose the name. You have to choose. I think it's because it's a prototype in Figma, but I think that designwise is clear*"	- Design features
"*Information is very clear.*"	- Design features
"*First, because I believe on this kind of system, I believe on the topic or looking into what the app is about*"	- Motivational factors for behavioural change - Topic interest
"*Second, because I think the system is well designed*"	- Design features
"*The colours and elements are consistent throughout all the tests. The functions that you are offering. The colours are nice, they are light and the green relates to the topic of the app*"	- Design features - Motivational factors for behavioural change
"*We are looking now at the mobile version of the system I'm used to use mobile too, so I think you have to test with people who don't have experience to see if you are going to get the same result.*"	- Inclusion
"*When we go to the one that you can add the challenge I only think that the one that for me was not easy to realise is where the suggestion action is. It's within the page where you have to create an event.*"	- Design features
"*It's not easy for me to understand why you have the map right? But you are suggesting the action you mentioned before, right? Where in your city you want to improve something or where in the city you want to ask that something can be change it right. It makes sense to be a map.*"	- Design features
"*And so I wonder how senior people will feel comfortable with a map. Maybe you could have another view. I know an old man (70 years), and he knew the city by heart, but just the fact he was looking at the digital map, he would get anxious.*"	- Inclusion
"*I like the icons and the colours.*"	- Design features
"*It's easy to see the colours. The names the the labels, the icons. And the position that the icons are on the screen, they are very easy.*"	- Design features
"*So maybe the concept of challenge has to be more clear. Because if I think that if I can grasp the concept of a challenge without having to look at any explanation then the concept of a badge will be easy to understand.*"	- Design features

Table 7.1: Table of themed data segments Participant 1 Iteration 1 (1)

Data segment	**Themes**
"*Challenge is such a great concept. I think it's hidden here. I think you have to put it in the spotlight. You have to find a way to put it in the spotlight. Because you have the idea of an event and of a suggested action, and the challenge can be a set of events and actions. Because you can push people to suggest actions too, right, so they commit.*"	- Design features - Gamification elements
"*I will have fun using it*"	- Motivational factors for behavioural change
"*And I am very curious to know if people from different backgrounds will think the same. Here we ask people, and they say it's not my problem, it's the government. Right now it's our problem because we live here we are*"	- Motivational factors for behavioural change - Citizen participation
"*I think if I could scroll in the map, it would be easier, right? If I could scroll, I would. Would get the sense that I can do things in different ways. So I think it works too, but if you have the time, I would think in another view for people who are not familiar.*"	- Design features - Inclusion
"*First because I believe that as citizens, each single person is responsible. To try to improve the place to live and our region and the country we live in.*"	- Citizen participation
"*So I believe in projects like that they call in the sense that they call it democratisation, right? We try to make it flat. So the people who use things, make decisions and you believe that those decisions are the best ones.*"	- Citizen participation - Inclusion
"*Yeah, you can relate to it and gets emotional, right? So I like very much the concept of the networking that you can be friends with people and you get a group of people to commit*"	- Motivational factors for behavioural change - Citizen participation
"*And I tried to develop projects that talked about these topics, but it's very hard because people are not educated to care about these things*"	- Inclusion
"*And feedback that I got from an old friend is like when you design gamification within your system, you have to concern on the backfire that the gamification can break. I'd say people might get very stressed out because they are being pushed to get badges or things like that.*"	- Gamification elements
"*This is what you have to look into. So I would say then gamify. You are going to consider gamification to promote the use of the system, but this is something that another student should take over in the future, we are just bringing the suggestion that it's important to have it. But we are not evaluating the design. Because gamification itself talks about motivation and motivation in not something that we learn how to design in the system. You have to be an expert in UX. Or you have to be an expert in psychology to learn how to motivate people. ***"	- Gamification elements

Table 7.2: Table of themed data segments Participant 1 Iteration 1 (2)

Data segment	**Themes**
"*'Get started', would have more liked something like 'Register' maybe*"	- Design features
"*I'm guessing it's the icon with the 3 something that looks like people, so I tap that. Here I see 4 people*"	- Design features
"*Yes, I guess mostly because I started on this page. Not necessary that way because the house told me that.*"	- Design features
"*So then I go to number 4 "Go to create" tab. Is it the magic wand? Yeah, that wasn't my first thought, but fun. Then I press create, because that's what I was supposed to do.*"	- Design features
"*It would have been a little more practical if the "Create event" thing came right away, and I didn't have to press edit.*"	- Design features
"*I think perhaps more intuitively would have been that all those filled in with name time location came as a "form" of some kind, but you understand what you have to do.*"	- Design features
"*And then I press publish. And there I could be allowed to press "return" yes. It was nice. It is not everywhere. It would have been nice to have it earlier, so you can get back*"	- Design features
"*The edit buttons are quite small, you understand in a way that they have to be, but if you are not very technical, then it is not so sure that you will see it so quickly*"	- Design features
"*It was also a bit, maybe not that easy ok, how many have you completed? I have completed 4 out of 6.*"	- Design features

Table 7.3: Table of themed data segments Participant 2 Iteration 1 (1)

Data segment	**Themes**
"*Personally, I don't think I would have used this app, because I have so much other things to do*"	- Motivational factors for behavioural change
"*And when I think about the environment, I think about little things I can do at home instead of in the city.*"	- Motivational factors for behavioural change
"*A cool concept if you want to find more people who do the same.*"	- Motivational factors for behavioural change - Topic interest
"*If you're motivated because there was something to do, you'd much rather do it with other people who also think the same than start going out on your own just because it's a bit nice.*"	- Motivational factors for behavioural change
"*It's nice that it's an app where you can motivate each other. I think like this; if you are not a student, then I feel that this is more natural to use because initiatives like this you can always do with a student organization or group of friends you have around you.*"	- Motivational factors for behavioural change
"*If you have moved to a new city and would like to get to know someone, and you like the climate, then this is a very nice app to get in touch with them and be able to do things together.*"	- Motivational factors for behavioural change

Table 7.4: Table of themed data segments Participant 2 Iteration 1 (2)

Data segment	**Themes**
"*A bit unsure of how to enter a name, or time or place OK, but I press create event anyway. Okay, I don't know what to do now.*"	- Design features
"*There were a lot of functions. A lot of cool functions too. But it was complicated to think that you have both points and badges and a lot of different things, but then I didn't get to know the system very much, but there was a lot of functionality which was a bit difficult to get to grips with. So it's a bit complicated in that you don't necessarily always understand that it wasn't so clear on, for example, naming and such.*"	- Design features - Gamification elements
"*It was perhaps a bit silly that the choices for an event comes up gradually, they should rather have shown all the choices at the same time. So that when you go to create an event, you see all the choices immediately(name, location, friends, time)*."	- Design features
"*I also think the location thing was a bit difficult, because I live in the city and I know the city well*"	- Design features
"*I would probably not need a technical person to use this app, bu I think my mom would have needed help*"	- Design features
"*I probably wouldn't have used the "challenge" part of the app too much. It is not so interesting when you have a busy schedule, then it is better to just see "oh they will do garbage collection in the park today, today I have time to join that*"	- Motivational factors for behavioural change
"*Challenges seems a bit harder to commit to. And I probably wouldn't made any events myself either*"	- Motivational factors for behavioural change
"*So it's cool to see what events are happening around the city that can contribute to the environment, for example, if I don't know about garbage collecting and such. So it's cool to have the opportunity to join something like that.*"	- Motivational factors for behavioural change
"*But the challenge part of it I don't think I would use much. It's not that interesting in a way when you have a busy everyday life, so it's better to just sort of pick up rubbish in the park.*"	- Gamification elements - Topic interest

Table 7.5: Table of themed data segments Participant 3 Iteration 1

Data segment	**Themes**
"*It would be better to to have the text under each one of the icons. But yes, I found it.*"	- Design features
"*If I create more than one event which suggested action it will be I'll be doing? For each event, if I create an event in my house and one event in Trondheim, so I have to create a suggested action in Manaus. How do I do that? I could not see this.*"	- Design features
"*It is not so clear that a challenge consists of several tasks*"	- Design features
"*I think that I would like to use this system frequently, yes. I like the idea of the app.*"	- Motivational features for behavioural change - Topic interest
"*I thought the system was easy to use yes.*"	- Design features
"*It was not so clear for me if the events and the actions were separate things or they are integrated things. *"	- Design features
"*Yeah, the idea of the applications is very good.*"	- Topic interest
"*If my friends and I were to use this application, it would be fun to collect badges*"	- Motivational factors for behavioural change - Gamification elements
"*I get motivated by competition, so the inclusion of points is great. Some of my friends would want more, more, more points, and therefore be motivated by this aspect.*"	- Motivational factors for behavioural change - Gamification elements
"*I felt the lack of interaction with my friends. Because here the interaction is only inviting people and accepting invites. So if I can send them messages, "hey, you're going behind and I'm earning more points than you", it would be great*"	- Motivational factors for behavioural change - Gamification elements
"*You can also get more points if you take pictures of the actions you're doing. It's like, oh I'm collecting trash on the streets, so I take a picture and post it so I get more points. It would be nice to have these kind of things*"	- Motivational factors for behavioural change
"*If you provide more interaction ways to communicate and to interacting with people would be better, but yes. I would be more motivated, yes*"	- Motivational factors for behavioural change
"*A leaderboard would be fun to see, and every badge you get. This you could then post on your social network. By this you also spread the word about your application*"	- Gamification elements

Table 7.6: Table of themed data segments Participant 4 Iteration 1

Data segment	**Themes**
"*The icon for feed looks like a house, which is intuitive*"	- Design features
"*I would like to use this system because the idea is interesting*"	- Motivational factors for behavioural change
"*It is a really helpful application, and kind of easy to use*"	- Design features
"*I had some problems with the badges on the profile, which I thought were clickable. I did not understand what they meant*"	- Design features
"*Usually we use a plus sign as the icon for creating something here in Brazil*"	- Design features
"*I know that abroad, the stick you have used as icon for the creating-section is widely used, but I havent seen it that much here in Brazil*"	- Design features
"*For me personally, I would think that the use of this application would make me more motivated to contribute for a better city, because I usually like these social projects*"	- Motivational factors for behavioural change
"*With the introduction of gamification in the app, it would also help a lot of my friends that arent that motivated as me to use these kinds of apps, to be more motivated to use them.*"	- Gamification elements
"*So I think that the introduction of gamification is a really great feature that would help a lot to get engaged with that*"	- Gamification elements
"*A feature that could improve the application is the ability to share things with friends*"	- Design features
"*To be able to see who used this app nearby me in the map, so I could talk to them and network with them. That would make a stronger community*"	- Motivational factors for behavioural change - Design features
"*Showing each user's points would be motivating, to have it more like a competition*"	- Gamification elements - Motivational factors for behavioural change - Design features
"*Earning points each time you suggest an action or creating an event could help motivate to the use of the app*"	- Gamification elements - Motivational factors for behavioural change - Design features
"*Competitions between cities would be motivating*"	- Gamification elements - Motivational factors for behavioural change - Design features
"*Should be possible to explore what other cities are doing, to get inspiration on how to act sustainable. This could be like Instagrams explore-page*"	- Gamification elements - Motivational factors for behavioural change - Design features
"*A chat where you could interact with other users would be really nice*"	- Gamification elements - Motivational factors for behavioural change - Design features

Table 7.7: Table of themed data segments Participant 5 Iteration 1

Data segment	**Themes**
"*I think it would be better to include the name of the sections in the menu, to make it easier for the users*"	- Design features - Inclusion
"*I think the action of creating an event should be in the event-section of the application*"	- Design features
"*Once I found the place where I can create events, it was easy to create events*"	- Design features
"*It was intuitive that my challenges were in my profile*"	- Design features
"*I dont see myself using the application. That is not related to the usability of the application, but about my own interest for using apps for climate change.*"	- Topic interest - Motivational factors for behavioural change
"*This application is motivating because you have interaction with other people where you can share what good you do for the cause*"	- Motivational factors for behavioural change - Design features
"*I think I would be motivated to change behaviour when seeing others doing something productive*""	- Motivational factors for behavioural change - Design features
"*For me personally, I would think that the use of this application would make me more motivated to contribute for a better city, because I usually like these social projects*"	- Motivational factors for behavioural change
"*It would be interesting to have separate tabs for creating events and suggesting actions*"	- Design features
"*It would be easier to understand if create an event and suggest an action are two separate things*"	- Design features

Table 7.8: Table of themed data segments Participant 6 Iteration 1

Data segment	**Themes**
"*It is nice that the sign up button calls more attention than the sign in button, since I dont already have an account*"	- Design features
"*It's a good design to have the 'get started here'-button*"	- Design features
"*OK, I like this user feedback that you gave me so I can I can get more information about what is going on. This is according to the usability heuristics of Jakob Nielsen*"	- Design features
"*I don't know if it is common in Norway, but in Brazil the icon for creating something is usually a plus-sign*"	- Design features
"*It is not so clear to me that I have to click on the edit button to choose the name, time and location*"	- Design features
"*I feel so lost now (when creating events)*"	- Design features
"*I think that all of this information should appear at the same time, so we can edit each one of them when we want*"	- Design features
"*It is a bit confusing with the concept of suggesting action. Suggesting action and creating events should maybe be separated*"	- Design features
"*The buttons on the menu should be named, because now it only shows the name when I click on them. That could have solved my problem with understanding the icon earlier*"	- Design features
"*The system should also give feedback to the user when I edit the location*"	- Design features
"*I would want to use this application frequently because I like the goal and objective of the app*"	- Motivational factors for behavioural change
"*The objective of the app is so interesting, and I agree a lot with the purpose*"	- Motivational factors for behavioural change
"*It is an important and necessary app*"	- Topic interest
"*The app should be more 'friendly' to new users, by providing more information. Maybe an optional tutorial?*"	- Design features
"*I would definitely become more motivated for environmental behaviour change after using this mobile application, because the world needs more initiatives like this*"	- Topic interest
"*I found the theme very interesting*"	- Topic interest
"*To get information about the context would be a nice feature to add. This could be in the form of a blog in the application.*"	- Design features
"*Some news related to initiatives and consequences on the theme would be nice. This would be more of an educational approach*"	- Design features
"*Badges is good for my motivation*"	- Motivational factors for behavioural change - Gamification elements

Table 7.9: Table of themed data segments Participant 7 Iteration 1

Data segment	**Themes**
"*And then I will add Mason, Olivia and Sophia as friends, maybe go to network tab then. There they are*"	- Design features
"*I have done 4 out of 5 days, if I have not done anything before...? I have at least done 4 consecutive days here*"	- Design features
"*How many points do I have and how do I rank? Maybe check my profile then (finds points), but where is the rank?*"	- Design features
"*They are good initiatives, but I don't see myself in an environment hver my friends and I hype eachother on these kinds of challenges*"	- Motivational factors for behavioural change
"*The four main tabs (feed, network, challenge and profile) helped me find almost everything*"	- Design features
"*Easy to use, I agree on that*"	- Design features - Motivational features for behavioural change
"*Yes, the app could have motivated me, but I would have needed other people around me who took initiative to do the challenges, but I don't think I would have been the one sending to my friends 'lets walk to work this week'*"	- Motivational features for behavioural change
"*To keep a streak can be motivating, to keep track of what you have done*"	- Gamification elements
"*Impact of what you have done would be nice, if you have got some point, what has that to do with the CO2 impact/your personal footprint*"	- Motivational features for behavioural change - Topic interest
"*Streak definitely motivates me*"	- Gamification elements
"*If you can use the points for anything external that is nice (like on Hold)*"	- Gamification elements

Table 7.10: Table of themed data segments Participant 1 Iteration 2

Data segment	**Themes**
"*It was okay to find the event, but I missed the button*"	- Design features
"*I guess that is me as it is marked with bold text*"	- Design features
"*If you get going I think it is nice, but I think there is a threshold at the start for something to happen*"	- Motivational factors for behavioural change - Topic interest
"*It was a bit hard to get overview with the prototype, because it is not dynamic and i.e. if you add friends they don't appear on the profile*"	- Design features
"*How do you make the challenges?*"	- Design features
"*It reminds me a lot of other apps, so I think most people would learn how to use it quickly*"	- Design features - Inclusion
"*Maybe you should have "Create event" as an own tab? Like Instagram, if that will be the main feature*"	- Design features
"*If there is a momentum, and that many people you know uses it, I feel it often works*"	- Motivational factors for behavioural change
"*Challenges like 'Walk to work' are nice*"	- Motivational features for behavioural change - Gamification elements
"*Easy to forget that you have this kind of apps, so it must provide some new and interesting content*"	- Motivational features for behavioural change
"*I liked the leaderboard, but you could have had a leaderboard with everybody on the app and not just the friends*"	- Gamification elements - Motivational factors for behavioural change
"*It is fun to compare yourself to everyone else*"	- Motivational factors for behavioural change
"*Head-to-head competitions makes you invested every time you go through to the next round*"	- Motivational factors for behavioural change - Gamification elements

Table 7.11: Table of themed data segments Participant 2 Iteration 2

Data segment	**Themes**
"*I want to add some more friends, then I want to go to the network tab*"	- Design features
"*I assume that I am the bold texted Jane Doe*"	- Design features
"*In reality I don't think I would have used it so often*"	- Topic interest
"*It was easy to use*"	- Design features
"*The popup box disappears very fast, don't have time to press close*"	- Design features
"*I think it could have been a good idea, but I would have needed more incentives than just the network to be motivated*"	- Motivational factors for behavioural change
"'*Hold' reward system could have been nice*"	- Motivational factors for behavioural change - Gamification elements
"*Points to buy rewards, external motivation factor to use those points for something you want*"	- Motivational factors for behavioural change - Gamification elements

Table 7.12: Table of themed data segments Participant 3 Iteration 2

Data segment	**Themes**
"*I found it a bit difficult to find 'Create event', because I knew that I was on 'Events', but it was a bit hard to know where it actually was*"	- Design features
"*It was really easy to find the information about the challenges*"	- Design features
"*If I am interested in the environment, and I have friends who also joins this challenges, a bit like Strava where you have people running and you also do running yourself, then it is interesting using apps like these*"	- Motivational factors for behavioural change
"*I am usually not very interested in these kinds of things*"	- Topic interest
"*It was not very complex*"	- Design features
"*When I was "deep into" events I had to remember that "Posts" and "Events" was on the feed, and as a new user I was unsure how to go back*"	- Design features
"*The popup only showed itself for 1 second*"	- Design features
"*It was consistent with many similar buttons, which did not make it confusing*"	- Design features
"*It gives me a social media vibe*"	- Motivational factors for behavioural change
"*(I believe most people would learn to use this system quickly.) I don't think it is hard to learn for either old or young people*"	- Inclusion
"*All these boxes tells me what I can do with the app*"	- Design feature
"*I was a bit unsure if these buttons was clickable*"	- Design feature
"*I think the app could have helped me become more motivated, and it helps that you find things you can do together with others*"	- Motivational factors for behavioural change
"*It is a higher threshold to do things alone, than to do it with others*"	- Motivational factors for behavioural change
"*Information about what I could do on a personal level also would have helped me, so more information about small actions to make it more relatable*"	- Motivational factors for behavioural change
"*Points is fun when I do it against people I know, but not against randoms*"	- Motivational factors for behavioural change - Gamification elements
"*To win against people I don't know, I don't care about that*"	- Motivational factors for behavioural change - Gamification elements
"*I like the challenges with 'step-by-step' small actions*"	- Motivational factors for behavioural change - Gamification elements

Table 7.13: Table of themed data segments Participant 4 Iteration 2

Data segment	**Themes**
"*I thought that only the active challenges were in the challenges section, and that my own challenges would be on my profile, but it also makes sense that all challenges are in that section*"	- Design features
"*I don't know how strong my personal motivation is to use this application*"	- Topic interest
"*Everything looks similar, design-wise, with the same types of buttons etc.*"	- Design features
"*To be able to make your own challenges would be nice, because then you can set your own goals in a way. Other users could also join these challenges". So it could be optional that others join, or you could just challenge yourself.*"	- Gamification elements
"*I felt a bit unsure at times*"	- Design features
"*Yes I think it would motivate me, especially the part with challenges are a bit fun, because then you can challenge yourself*"	- Motivational factors for behavioural change - Gamification elements
"*Badges are also kind of a motivational factor*"	- Motivational factors for behavioural change - Gamification elements
"*Personally, I am a bit unsure if the networking part of the application would be motivating for me*"	- Motivational factors for behavioural change
"*It would be cool to connect to the people close nearby, maybe with the people in the same housing association you live in*"	- Design features - Motivational factors for behavioural change
"*Leaderboard is kind of fun*"	- Design features
"*(On Hold), it is motivating that others can see that you are doing a good job*"	- Motivational factors for behavioural change
"*To see what you have accomplished is motivating, because then you see how well you have done in the past*"	- Motivational factors for behavioural change
"*What is the difference between events and challenges?*"	- Design feature

Table 7.14: Table of themed data segments Participant 5 Iteration 2

Data segment	**Themes**
"*I think I would be motivated using this application, because it is cool that you have friends where you can do it to a competition with leaderboards. So I think I would be motivated to continue to use this application, if I first had started using it, and people also used it*"	- Motivational factors for behavioural change - Gamification elements
"*I would be motivated to continue the use with this application, but with precaution that others also used it*"	- Motivational factors for behavioural change
"*If I was the only user of this application, I wouldn't have any motivation to use the application*"	- Motivational factors for behavioural change
"*I miss some pictures in the feed*"	- Gamification elements - Design features
"*It would have been more fun to see pictures of people when they are contributing*"	- Design features - Gamification elements
"*I think the use of points where you actually can use these points outside of the app, would be extra motivating for me, especially when the focus is on the climate*"	- Motivational factors for behavioural change - Gamification elements
"*On Hold (app) you can also see when your friends are "holding" and I find that motivating, which is something similar to what you have in this application*"	- Motivational factors for behavioural change - Gamification elements

Table 7.15: Table of themed data segments Participant 6 Iteration 2

Data segment	**Themes**
"*I probably could have used this system often, but I do not feel a burning desire to use the application*"	- Topic interest
"*It would have been nice if the events appeared on your own profile*"	- Design features
"*Your newly created event should appear in the feed*"	- Design features
"*To make it like a social media where you can compete with friends is fun and a motivating factor*"	- Gamification elements - Motivational factors for behavioural change
"*I think it is crucial to involve/add challenges that you dont usually do, so you would need the app to complete those challenges*"	- Gamification elements - Motivational factors for behavioural change
"*I walk to school everyday anyways, so I wouldnt use this application just to register that I have walked to school*"	- Topic interest
"*I think that the leaderboard is motivating*"	- Motivational factors for behavioural change - Gamification elements
"*The aspect of friends is motivating, to know that people you know are gathered in one application*"	- Motivational factors for behavioural change
"*Competition is something that works largely for me, I have a lot of competitions with friends on Apple Watch*"	- Motivational factors for behavioural change - Gamification elements
"*I don't know if the use of badges would have worked that much for me*"	- Motivational factors for behavioural change - Gamification elements

Table 7.16: Table of themed data segments Participant 7 Iteration 2

Chapter 8

Discussion

This chapter discusses the findings from the focus group interview in Chapter 5, the mobile application prototype in Chapter 6, and the usability testing of the prototype in Chapter 7. These discussions address the research objective of this thesis, in relation with other solutions and theories.

In this research project, we propose a mobile application prototype for encouraging environmental behaviour change for citizens in cities by making use of gamification and social aspects. Through the use of a focus group interview and two iterations of usability testing, valuable insights were gathered to design a mobile application that motivates citizens to contribute to a sustainable and inclusive city. The findings highlighted key motivational factors, including the social aspect, flexibility, and the desire to make a difference. The results also revealed that the implementation of various gamification elements has the potential to drive citizens' environmental behaviour change. Specific gamification elements such as rank, leaderboards, rewards, and task completion tracking were identified as effective motivators. By incorporating these findings into the application requirements, the digital platform can effectively engage and motivate citizens, fostering their active participation in creating a sustainable and inclusive city. These results will be discussed thoroughly in this chapter, comparing and relating them to other solutions and theories.

The outline of this chapter is as follows: The results related to RQ1 are discussed in Section 8.1, regarding the focus group in Section 8.1.1, usability testing in Section 8.1.2 and SUS scale in Section 8.1.3. The results related to RQ2 are discussed in Section 8.2, the implications for practice are discussed in Section 8.3, and the limitations of the work are listed and discussed in Section 8.4. Lastly, recommendations for future development are discussed in Section 8.5.

8.1 RQ1: How Should a Digital Platform Be Designed to Motivate Citizens to Contribute to a Sustainable and Inclusive City?

This research question aims at finding both motivational factors for using a digital platform for citizens to contribute more to sustainable and inclusive cities, and also finding out what design elements should be included in a mobile application for this purpose. Both theories and results from focus group and usability testing have helped answer this research question.

8.1.1 Guidance of Design Through Focus Group Interview

The development of mobile application design guidelines and the proposed solution presented in Chapter 6 was guided by a focus group interview session with participants from the SBS research group at NTNU. This focus group interview provided helpful guidance on how to design the mobile application to help answer RQ1. In general, the use of a focus group interview as a data collection method to guide the design of the application, and encourage a discussion on motivational factors among potential users of the solutions, provided value to the project. Focus groups are reported to be successful in evaluating IT design artefacts [101], but in our case, this method worked well to confirm or refute indications from the SLR [8] and other theories, and therefore provide more knowledge on how to design the application. The opinions, beliefs and reflections provided by the participants provided valuable insight into some questions supporting our research objective.

The focus group interview led to some interesting findings, which were important to the development of the evaluated prototype and application requirements to answer RQ1. When asked about the motivation for voluntary work the participants outlined the social aspect of meeting like-minded people, in order to feel belonging and being together about solving a problem. Lee *et al.* outlines the creation of social groups as a possibly powerful strategy for affecting behaviour change, and specifically for our purpose, online environments have shown promise in creating social groups with a shared interest for climate change [97]. The social aspect of motivation is outlined in Fogg's FBM as one of the three core motivators for human behaviour, and that social acceptance or rejection controls much of people's social behaviour [47]. Fogg also points out that social technologies can be used to motivate and influence users because of this core motivator.

The focus group also highlighted information about the problem as an important motivational factor, to make the users relate and understand why they should care. Rajanen and Rajanen outline some issues regarding climate change communication, stating that traditional mass media communication has shown low effect in changing environmental behaviour for individuals, mostly because people struggle to perceive it as a personally relevant issue and rather as something distant in both time and space [26]. Although the need for effective communication of the problem is an interesting point, information on more sustainable

behaviour alone can not be seen as a sufficient motivational factor [67]. This is also supported by the TTM, as *counsciousness raising - increasing awareness about the healthy behaviour* would only cover a few early stages of change, and therefore would not be able to change behaviour alone. This has been taken into account when developing the design guidelines and prototype, to make sure the solution facilitates an actual behaviour change.

Some features to steer clear of when designing the application were also mentioned by the participants, as they reflected on features that could avoid them from using the application. It is worth mentioning that those reflections were made on a general basis, and not specifically with our application idea in mind, but nevertheless, they provide interesting insights that we considered when designing the first versions of the prototype. There were mixed opinions on the use of ads and pop-ups, but the overall impression was that ads and pop-ups, often an important source of revenue for app developers, can be demotivating and cause users to stop using an application. In addition, the feeling of boredom was outlined as an important part in demotivating users, if they do not feel that they are sufficiently engaged or stimulated by using the application. Lastly, the concept of dark design and manipulation was brought up. Gray *et al.* defines *dark patterns* as 'instances where designers use their knowledge of human behavior (e.g., psychology) and the desires of end users to implement deceptive functionality that is not in the user's best interest' [102, p. 1]. It is of high importance that the application has an ethical design without manipulative or dark patterns, both for inclusion and protection of all users, and to facilitate for citizens being motivated to use the application.

Based on the discussions held during the focus group interview, as also explained thoroughly in Chapter 5, there are clear indications that a developed mobile application platform will help motivate citizens to contribute to a sustainable and inclusive city.

8.1.2 Evaluation Through Usability Testing

The gathered data from usability testing of the mobile application prototype were also important to answering the research questions, especially RQ1. Usability testing was chosen due to ease of organization, participant recruitment and valuable feedback from the users. No UX designer has the ability to create a good enough user experience without using iterative design guided by observations and feedback from actual users interacting with the design, as the number of variables in the human brain and in designing a good user interface combined is huge [81]. Hence, conducting iterative testing with actual users holds significant importance for our objectives and will continue to be crucial during the further development of the application. Our qualitative approach to usability testing, collecting insights, opinions and pain points in the design and motivation has been essential to answering the research questions and guiding further development of the application.

Similarly to the findings from the focus group interview, the importance of social aspects in the application was highlighted as a major motivational factor to contribute to a sustainable and inclusive city. According to the FBM, one of the subcomponents of motivation is *social acceptance/rejection*. Considering this subcomponent, Fogg states that humans seek social acceptance and avoid rejection, which can be related to the participants stating that it is motivating when others can see that you are doing a good job, ultimately talking about social acceptance. Fogg uses Facebook as an example, where the users posting content are driven significantly by their desire to be socially accepted, which aligns with the usability testing findings. The importance of connecting with others on the application is also reported as a motivation for the continuation of use. In relation to the TTM, this aspect fits in with the *Action and Maintenance* stages, and these are crucial to maintaining a behaviour change for an individual.

The participants' statements about the motivational factor when seeing others doing something productive are in line with the theory of Lee *et al.* [97], stating that forming social networks around individuals that normalise desired behaviour may be a powerful technique for promoting behaviour change. These findings are consistent with Abrahamse and Steg's research, suggesting that social influences effectively influence individual behaviour, particularly in relation to sustainable behaviour [103]. Specifically, individuals tend to adjust their behaviour when observing a specific social group exhibiting a certain behaviour [67]. The usability testing results indicate that the application's social community can serve as that specific social group. Furthermore, this can be connected to the expected outcome of an action, the anticipation of hope or fear, playing a significant role in driving motivation according to Fogg [47]. By witnessing the positive influence of others in the application, users can anticipate positive outcomes, leading to increased motivation. As Fogg suggests, hope is considered the most ethical and empowering motivator. Therefore, by instilling hope through the observation of others' positive impacts, motivation can be further enhanced.

As in the focus group interview, the participants of the usability tests highlighted the importance of information in the application. The information on events, already implemented in the prototype, was confirmed as a nice feature as the information would make it easier to join and contribute to these events. The suggestion to add some additional information on how to contribute to the cause on a personal level is interesting, as this was the idea behind the feed of the application. Following a crowdsourcing approach, based on how Remelhe *et al.* [69] make the users themselves contribute with information, the idea was that the users of our application would post information in the feed about how to contribute sustainably to the cause. Concerning the participants of the usability testing stating that more information was needed, this could be due to the fact that there was a lack of interaction with the feed during the completion of the different tasks and activities. It could also be that the feed in itself is not enough, and that more information on news and initiatives related to the problem should also be added in some kind of a blog feature in the application, as another participant sugges-

ted. This informational approach in the application would fit in with the two first stages in the TTM [46], where the information could contribute to the users being aware of their behaviour, and contribute to making the users more thoughtful of the pros and cons of changing behaviour. As outlined in Section 8.1.1, while this alone may not be adequate for inducing behaviour change, it represents an initial step in the process. Nevertheless, when considering the implementation of additional information in the application, it is important to reflect on where to obtain this information, to ensure that the information is correct and not biased.

An important aspect to consider for further development of the prototype is the inclusion of a chat feature that allows friends to interact with others. This suggestion was made by participants in the usability testing, who expressed that this feature would enhance their motivation. Additionally, the literature supports the idea that a chat feature could boost motivation. Luger-Bazinger and Hornung-Prähauser found a positive impact on users' mobility behaviour when their application sent nudges comparing their behaviour with that of other users [67]. As mentioned by a participant in the usability testing, the chat feature could function in a similar manner, with users sending nudges to each other, thereby further increasing motivation to contribute.

The participants in Iteration 1 highlighted the importance and need of an application like ours and their interest in the theme, which can be connected to *Core Drive 1 Epic Meaning and Calling* in Octalysis, as this is the drive where people are motivated because they believe they are involved in something greater than themselves [104]. It can also be related to the hopes and fears that influence the desire to take action, as stated in the FBM, because hope can be harnessed to motivate individuals' desire to contribute to or participate in something meaningful [105]. However, during Iteration 2, a shift in participant perspectives was observed, with some displaying more scepticism. Particularly noteworthy was Participant 7, who did not exhibit a strong inclination to utilise the application despite previously acknowledging the motivating factors of the leaderboard and the competitive and social aspects. The participants' suggestion on incorporating challenges that users typically do not engage in independently, thereby necessitating the application's involvement to complete those challenges, should therefore be taken into consideration. By integrating these types of unique challenges, it is possible to enhance Participant 7's motivation and increase their inclination to use the application.

Design feedback

The results obtained from the usability testing align with several heuristics proposed by Nielsen [106]. In Iteration 1, participants expressed the need for improvements related to the navigation bar. Specifically, some participants found the icons confusing, particularly the icon representing the action of creating a task. Participants 5 and 7 suggested using a more intuitive icon, such as a plus sign, which is commonly associated with the "create" action in Brazil. Additionally, participants recommended naming the icons to enhance user navigation within

the navigation bar. This feedback aligns with Nielsen's fourth usability heuristic, emphasizing external consistency and the importance of using familiar and recognizable icons. After incorporating the recommendation to name the icons in the navigation bar, no further feedback regarding this aspect was received from participants during Iteration 2. This indicates that the implemented change was successful in addressing the participants' previous concerns and resulted in improved usability and clarity in navigating the application.

Furthermore, suggestions were made in Iteration 1 to modify the information input form to allow users to fill in all the required details simultaneously. Participants 2, 3, and 7 supported this idea, highlighting that it would offer more intuitive control and freedom to edit each section as needed. This recommendation corresponds with Nielsen's third usability heuristic, emphasizing user control and freedom in the interface design [106]. No further feedback regarding this aspect was received from the participants after implementing the suggested change, again indicating that the implemented change was successful in addressing the participants' previous concerns.

During Iteration 2, feedback regarding pop-up notifications for user feedback was provided. Participant 3 noted that the pop-up box disappeared too quickly, leaving insufficient time to read the feedback. Participant 4 also highlighted the short duration of the pop-up, with both participants attempting to close the box before it vanished. This observation aligns with Nielsen's first heuristic [106], emphasizing the provision of appropriate feedback within a reasonable timeframe to keep users informed about ongoing processes, and the pop-up box should be changed accordingly.

8.1.3 System Usability Scale

The average SUS score showed an improvement from 80.7 in Iteration 1 to 86.1 in Iteration 2, suggesting a potential enhancement in the overall usability of the prototype after implementing the suggested improvements from the first iteration. These results are supported by the comparison of observations and feedback received during Iteration 1 and Iteration 2. In Iteration 2, the usability issues that participants faced during Iteration 1 were mitigated, and the feedback obtained from think-aloud and discussions in Iteration 1 primarily revolved around design-related confusion and usability concerns, whereas in Iteration 2, these aspects were less prominent.

Despite Brooke's caution against extracting meaning from individual questions of the SUS, emphasizing the composite measure of overall usability [92], Lewis and Sauro [100] have developed regression equations to establish benchmarks for specific SUS questions. While Brooke's statement relied on data from only 20 individuals, Lewis and Sauro had a significantly larger dataset and determined that analyzing certain SUS questions individually, such as Question 2 (perceived complexity), Question 3 (perceived ease-of-use), Question 6 (perceived consistency), Question 7 or 10 (perceived learnability), and Question 9 (confidence in use), can

be valuable. In Iteration 1, as shown in Figure 7.3, the average score for Question 2 is below the benchmark required to achieve a total SUS score of 80. However, in the second iteration, the average score for Question 2 surpasses the benchmark, as depicted in Figure 7.6. Additionally, there is an increase in individual scores for Questions 3, 6, 7, and 10 from Iteration 1 to Iteration 2. This indicates a decrease in perceived complexity and an improvement in perceived ease-of-use, consistency, and learnability after implementing the changes described in Section 6.3. Nevertheless, in both iterations, the scores for Question 9, which evaluate perceived confidence in use, remain below the benchmark. This suggests that there is still room for enhancing usability in future iterations.

As stated by Fogg 'persuasive design succeeds faster when we focus on making the behaviour simpler instead of trying to pile on motivation' [47, p. 6]. By facilitating the desired behaviour through the application, and making the application easy to use, the behaviour will arguably become simpler to do, thus increasing the change of a behaviour change. The perceived ease of use indicated by the high score of Question 3 in Iteration 2 is therefore an indication that the prototype can promote the desired behaviour change. The above-average SUS score of 86.1 can also be attributed to Fogg's concept of ability, which plays a crucial role in influencing behaviour change. By presenting a highly usable prototype, we empower users with the necessary capabilities.

8.2 RQ2: Which Specific Gamification Elements Should Be Implemented in Such a Digital Platform to Make Citizens Change Environmental Behaviour?

This research question aims at providing knowledge into the effect different gamification elements have on individuals' motivation, also connected to a desired environmental behaviour change. This research question is mainly answered by the results of the usability testing, however, theories and focus group results also partially contribute.

In the results from the usability testing, it was found that while a number of participants expressed that the social features provided motivation, during the second iteration, some of them highlighted that relying solely on the social aspect of the application would not be an adequate motivational driver to use the application. They emphasized the need for additional incentives and features to further enhance motivation and engagement with the application. This insight suggests that while the network features may serve as a source of motivation, they should be complemented with other elements to ensure sustained user engagement. Gamification elements can be such elements. Although not being the main focus of the focus group interview, gamification and the use of gamification elements to increase motivation were partly discussed. The participants highlighted a broad variety of gamification elements to make them motivated. They did not agree on any specific preferred elements, but the discussion gave a clear indication

that they see themselves being motivated by gamification in mobile applications.

In order to encourage citizens to modify their environmental behaviour, several gamification elements have been implemented within the application. One such element, challenges, was found to be highly appreciated during usability testing, as indicated by participant feedback. This aligns with the findings of Ferron *et al.* [65], who reported that challenges were the most well-received motivational element in their sustainable mobility application. Ferron *et al.* also noted that while challenges can effectively stimulate behaviour change, they can also become bothersome for users. Accordingly, they emphasize the importance of carefully tailoring challenges to each individual user. They propose that behaviour change challenges should be incorporated as additional challenges, featuring an appropriate number of points. The motivational impact of challenges on behaviour change is well-supported by various theories. Overcoming challenges is an integral aspect of Core Drive 2 in Octalysis, providing motivation for engaging in specific activities. In terms of behaviour change, challenges can be linked to different stages and processes in the TTM. Challenges can assist users in progressing towards and maintaining behaviour change, particularly during the Action and Maintenance stages. This is achieved through counterconditioning, as challenges help users replace unsustainable behaviour with sustainable alternatives, a viewpoint supported by Cellina *et al.* [99]. Prior to the *Action* and *Maintenance* stages, challenges can also be viewed as a component of the preparatory phase in the TTM. By embracing the notion of personal transformation and making a firm commitment to act upon that belief, users who register for challenges align themselves with the self-liberation process of change within the TTM.

The role of badges in motivating participants is closely tied to the concept of challenges, where badges are earned upon their completion. Opinions regarding the significance of badges in terms of motivation varied among the participants. While some acknowledged the positive impact of badges on their motivation, others expressed scepticism about their effectiveness. This scepticism aligns with the findings of Ferron *et al.* [65], who observed that badges were the least valued motivational element by the users of their application. To enhance the motivational impact of badges, Ferron *et al.* suggest incorporating points into badges and increasing their visibility, such as displaying them alongside users' nicknames on their profiles or on leaderboards. This idea of improved visibility resonates with the findings of Lee *et al.* [97], where the implementation of publicly viewable profiles and their status were implemented to promote positive peer pressure. By making badges more visible, the promotion of positive peer pressure could be facilitated. Additionally, displaying badges prominently not only taps into the desire to showcase one's achievements but also aligns with the motivational factor of demonstrating competence highlighted in the usability test results in Section 7.1.1.

During the usability testing phase, participants expressed varying perspectives on the points system. Some participants found it to be a motivating factor, aligning with the pleasure and pain dimension of the FBM, which suggests that

humans tend to engage in behaviours that lead to positive outcomes [107]. In this case, points can serve as a positive outcome for the user. The use of points is also supported by Core Drive 2 in the Octalysis Framework, reinforcing the participants' claims of finding the points system motivational. Furthermore, the points system can be linked to the *Action* and *Maintenance* stages in the TTM, as it provides a form of reward for making changes, thus facilitating the reinforcement management process of change in the TTM. However, while some participants found the points system inherently rewarding, others mentioned that the points themselves lacked intrinsic value and only became rewarding when used for external incentives. This contradicts the motivational aspect of points according to the TTM, Octalysis, and Fogg's Behavior Model. In line with these findings, Ferron *et al.* [65] discovered that the points implemented in their application were generally not motivating on their own. However, they became motivating when users accumulated enough points to secure a high position on the leaderboard, thus increasing their chances of winning a prize.

According to the participants in the usability testing, leaderboards were identified as a motivating factor. Similar to challenges, badges, and points, leaderboards fall under Core Drive 2 of the Octalysis Framework, indicating their potential as a motivational element. However, it is essential to implement them correctly. Van Diepen [108] points out a common mistake in leaderboard implementation, emphasizing that a basic leaderboard where users are ranked from first to last place can lead to demoralisation among mid and lower-ranked participants. This view aligns with the findings discussed by Ferron *et al.* [65], where interviewees expressed dissatisfaction with leaderboards that were consistently dominated by a few highly active players. Sailer *et al.* [109] also raise concerns about leaderboards, noting that they can be seen as critical since only a select few will occupy the top positions, potentially leaving the majority of players feeling demotivated when placed at the bottom. Leung [110] also indicate that users closer to the bottom of the leaderboard get demotivated. In contrast, Van Diepen suggests an alternative leaderboard design that focuses on regional or friend-based rankings, promoting a sense of optimism [108]. Creating several separate leaderboards is also discussed by Ferron *et al.*, further stating that this might mitigate the negative effect of global leaderboards [65], [109]. However, it should be noted that one participant in the usability testing suggested including a leaderboard with everyone on the application, indicating a divergence of opinions on this matter. Leung supports this notion stating that 'the effects of increased heterogeneity in leaderboards are not as straightforward as believed' [110, p. 10]. As a result, Leung suggests the continuation of classic leaderboards.

The concerns raised during Iteration 1 of usability testing regarding gamification can be examined through the lens of the Octalysis Framework. Users expressing stress due to their perceived lack of progress in acquiring points and badges aligns with some unwanted effects of Black Hat Gamification within Octalysis. However, since none of the core drives associated with Black Hat Gamification was implemented in the prototype, these concerns can be addressed and mitig-

ated. Additionally, the suggestion to incorporate a streak feature in the application, aimed at motivating users, can also be linked to Black Hat Gamification, specifically *Core Drive 8: Loss and Avoidance*. The introduction of a streak mechanism would leverage the fear of losing one's streak as a motivator. This suggestion can also be connected to the motivational subcomponent of fear and hope within the FBM. Although being related to both Octalysis and the FBM, showing promise in motivating and facilitating for behaviour change, these kinds of features can end up making the users develop unhealthy obsessions or even addiction[1]. Therefore, the implementation of these kinds of features should be approached with caution to mitigate such risks.

8.3 Implications

This research study provides several implications for practice. The SLR investigated digital support for climate-neutral, inclusive and beautiful cities, outlining a minimal amount of solutions developed for the objective of the European Green Deal and using digital technologies to meet the climate targets in an inclusive way. However, the SLR identified some digital technologies and techniques that could be used to provide more knowledge on this field of study.

Our developed mobile application solution presents a way to help motivate citizens to change environmental behaviour, a possibly powerful tool which can help cities and local communities become more sustainable. Additionally, studying how to motivate citizens and promote environmental behaviour change in an inclusive way contributes to the limited number of empirical studies on how climate neutrality can be reached in an inclusive way with the use of digital technologies. The solution builds on existing theories and suggestions and aims to be a helpful tool to provide more knowledge on the field, and the limited research on the field implies that the area should be further studied. The insights, tools and results from this project will help practitioners and researchers move forward. Based on the results, we argue that the application requirements and the proposed solution are suitable first steps towards understanding how to design an inclusive mobile application to change individuals' environmental behaviour, which can be an important tool to help reach the climate targets in an inclusive way. However, there is a need for more empirical evidence supporting our initial positive results.

Through this research study, we both aim to provide a tool that should be further researched and also act as an inspiration and motivation for further research on the area. Further research will provide more insights, confirming or contradicting, into how digital technologies should be used to address the ongoing climate crisis in an inclusive way.

[1] https://yukaichou.com/gamification-study/white-hat-black-hat-gamification-octalysis-framework/

8.4 Limitations

This research project involves several limitations, which are deemed relevant to our research objectives. The sample size of usability testing was limited to 14 participants over 2 iterations, with 7 participants in each iteration. This number of participants may introduce limitations concerning the calculated SUS scores. Although Tullis and Stetson report that a sample size of 12 or more gives a 100% accuracy of the SUS score, the design changes made between the two iterations make it less suitable to combine the SUS score of all 14 participants. Tullis and Stetson have not reported the percentage of "correct" conclusions for a sample size of 7, but it is worth mentioning that a sample size of 6 gave 35% accuracy and a sample size of 8 gave 75% accuracy [111]. Therefore, the SUS scores should not be seen as an accurate generalisation of the target population, but the results, either way, provide interesting insights into how the participants experienced the usability, and participants "thinking aloud" while answering the SUS questionnaire also provided valuable insights. Possibly, a sample size of 8 for each iteration, 16 in total, would have provided more stable SUS results, with a proven 75% accuracy for each of the iterations, and over 15 users in total, the number deemed necessary to discover all usability problems in a design [82]. However, in the curve shown by Nielsen [112, Figure 1], a number of 14 test users gives a score of almost 100% usability problems found, which we deem a suitable result for our early design research.

Another limitation that must be taken into account in this research project is the use of convenience sampling for participant recruitment. As the participants for the focus group interview and the usability testing were recruited using a convenience sampling technique, the sampling was not done randomly. Therefore, the participants cannot be seen as a general representation of the target population, as they only represent a limited group of people. Therefore, the results from the usability testing sessions do not reflect the opinions of a diverse target population, but rather a subgroup of academics. This limitation should be addressed in the future evaluation of an improved prototype or product.

Due to the limited time period of this research project, and the aim of answering the research questions as precisely and thoroughly as possible, we rather prioritized doing two iterations of development and evaluation of a prototype, than developing a coded Minimum Viable Product (MVP) of the mobile application. Therefore the evaluation of the prototype restricts addressing design and UX, while the evaluation of an MVP would be more realistic as it would be more similar to the finished product. For instance, the prototype does not have working input forms, making some parts of the interaction rather artificial. Although the participants were aware of this drawback and seemed to not be too much affected, there is a risk that this might have influenced their overall usability experience.

8.5 Recommendations for Future Development

Based on the development and positive responses from the evaluation of the mobile application prototype, we strongly encourage further development of the application. One suggestion for future development is that the mobile application can be implemented, potentially using the proposed technology stack from Section 6.4, resulting in an MVP to be further tested and iterated. This involves choosing what databases to use, and also what backend and frontend to use for the application. This product will be closer to an actual product and will therefore help proving more knowledge on the field of study as the evaluation will be more realistic. Therefore, this is deemed necessary to provide more knowledge on the field and on how the application should be designed and used in the best possible way regarding the objectives. We suggest using our requirements and results to guide the development, as we provide thorough design guidance. Additionally, as mentioned in Goal 5 of the application requirements, the design of the application should be inclusive, providing equal opportunities for all users, and this must be in focus in future development.

When it comes to further design of the application, we recommend that further work include deciding on a name and designing a logo for the application. We believe that incorporating these aspects can effectively motivate users to engage with and remain active on the application. This represents a potentially significant step towards creating an appealing platform that caters to all users. Due to time constraints, we chose not to design a logo or find a name for the application, as we did not deem it a necessary part of our project. A possible approach to making a first logo and a name for the application, is using generative AI, as is increasingly popular and shows promise as being a very powerful tool both when it comes to generating text and images.

Chapter 9

Conclusion

This research project consisted of following a design and creation research strategy with the objective of increasing individual citizens' motivation to change environmental behaviour through the design and evaluation of a mobile application prototype. As part of this research strategy, we conducted one focus group interview and two iterations of usability testing, to help answer the research questions. The following sections will present conclusions made regarding the research questions and also directions for future studies.

9.1 RQ1: How Should a Digital Platform Be Designed to Motivate Citizens to Contribute to a Sustainable and Inclusive City?

The results of this study indicate that a mobile application is a suitable digital platform to motivate citizens to contribute more toward reaching the goals of the European Green Deal, namely reaching zero greenhouse gas emissions by 2050 in a just and inclusive way. The developed application requirements and mobile application prototype presented in this study, as presented in Chapter 6, contribute to knowledge on how to design such a mobile application and on which specific design elements should be included.

Through the SLR, the focus group interview, and the evaluation of the application, several specific motivating elements have emerged, that could help motivate citizens to contribute to a more sustainable city. Social aspects have been highlighted by the participants as largely motivating, and therefore the application should be designed in a way that makes it easy for users to connect with others and feel they are part of a community working towards the same goals. Therefore, registration and identification of users are necessary to facilitate the creation of a network. There are several ways to implement social aspects into such a mobile application, but the user should at least be able to befriend other users. Gamification elements also have shown to be motivating for the participants, and therefore should be included in the application. People seem to have different opinions on

which specific gamification elements they are motivated by the most, but the use of challenges to compete with other users showed potential as a motivating aspect to make people engage more towards a sustainable city.

While it is demonstrated that displaying information alone may not be sufficient to convey the problem's significance to individuals, it is emphasised that doing so plays a crucial role in inspiring citizens to contribute. Participants have expressed the importance of receiving clear and relatable information that illuminates the reasons they should be concerned and outlines ways in which they can contribute to the cause. The application should incorporate functionalities that promote consciousness, enhance awareness, and offer insights into sustainable behaviours and initiatives, and the implementation of a feed where other users' contributions appear, information about initiatives through a blog in the application and facilitation of events are found to be suitable ways to incorporate these functionalities in the application.

Generally, a simple and straightforward design has been shown to be important for motivational aspects, and this also fosters inclusion. The results and observations underscore the significance of avoiding unnecessarily complex application designs, as they contribute to user confusion and subsequent loss of motivation. The application should be designed in an inclusive way, both to provide equal opportunities for all users of the application to be a part of the community and for motivational reasons, as complex design could be a demotivating factor. With the obtained SUS score of 86.1 in the last iteration, we conclude that the developed application prototype scores well on usability, laying a good foundation for further design and development.

9.2 RQ2: Which Specific Gamification Elements Should Be Implemented in Such a Digital Platform to Make Citizens Change Environmental Behaviour?

The results of the two iterations of usability testing and the focus group interview shed light on the effectiveness of gamification elements in influencing citizens' environmental behaviour. A prominent gamification element that was highly appreciated by the participants was challenges. Challenges were found to stimulate behaviour change and motivate users to engage in specific activities. However, it is important to tailor challenges to individual users and incorporate an appropriate number of points to not overwhelm or bother users.

The badges' effect on participants' motivation was found to be varied, with some acknowledging their positive impact while others expressed scepticism. To enhance the motivational impact of badges and consequently improve the likelihood of a change in environmental behaviour, it is suggested to incorporate points into badges and increase their visibility, such as displaying them alongside usernames or on leaderboards. This visibility not only taps into the desire to showcase achievements but also promotes positive peer pressure, as seen in previous stud-

ies.

The points system was found to be motivating for some participants. However, it was also mentioned that points themselves lacked intrinsic value and only became rewarding when used for external incentives. Including points as a gamification element should be implemented to make citizens change environmental behaviour, and the implementation of using points for external incentives should be considered, improving the likelihood of behaviour change.

Leaderboards were found to be a motivating factor and should be implemented to increase the likelihood of citizens changing their environmental behaviour. However, it is crucial to implement leaderboards correctly to avoid demoralisation among users. Alternative leaderboard designs, such as regional or friend-based rankings, can promote a sense of optimism and mitigate the negative effects of global leaderboards. To address the divergence of opinions among users and maximize the potential for leaderboard motivation within the application, it is recommended to implement various types of leaderboards, including global leaderboards. By incorporating multiple leaderboard variations, the application can cater to different user preferences and give each user an optimal chance of being motivated by a leaderboard. This approach ensures inclusivity and enhances the motivational impact of leaderboards for a broader user base.

Given the potential overlap between Octalysis and the FBM, the implementation of a streak feature should also be considered in the application, to further motivate and facilitate behaviour change. However, the feature should be implemented in a way that minimises the negative effects such elements can have on users.

9.3 Future Work

Based on the development and responses from the usability testing, there are several areas that need further investigation. We suggest that the application is further tested on a randomly sampled population to produce results representative of the largely diverse target population of the application. As the participants in this project represent a limited amount of the population and are not chosen randomly, there is a need to test with a larger diversity of participants. As one of the main motivating concepts of the solution is inclusion, this is important to further address. Testing should also be considered with people with different disabilities, to access the goal of inclusive design and facilitate reaching the objectives in an inclusive way. We also suggest that the iterative design and creation research strategy is continued by making the prototype into an actual mobile application, possibly following the suggestions in Section 8.5.

In addition, human behaviour is an extremely complex field of study that goes far beyond the objectives of this project. Further studies should focus more on this psychological aspect, especially when it comes to design and implementation of gamification elements to make individuals change behaviour, while doing it in an ethical and inclusive way without manipulating, exploiting or excluding anyone.

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Appendix A

Project Description TDT4501

Investigate Digital support for inclusive, beautiful, climate neutral cities

To be accepted as a Master's student, you need to participate to the 9th ACM Celebration of Women in Computing, WomENcourage 2022, that is going to take place in Larnaka, Cyprus 21-23 September, 2022! You will have to write a poster that is going to be presented at the conference.

This thesis will build on existing bulk of knowledge about gender and diversity in software development (TDT10) to provide increased knowledge and solutions about the relation between digital support and inclusiveness for the cities of the future.

The work will be connected to the COST Action CA19122 EUGAIN, Project CityxChange, the New European Bauhaus, and EU Project CrAFt.

Specifically in this thesis, the students will propose one or more goals to investigate. The general research question is "What is the relation between Digital Support and specific SDGs like the SDG5?".

The students will:

1. Run a systematic literature review of the theme.
2. Plan an empirical investigation.
3. Run an empirical investigation .
4. Propose new information sources which address gender and diversity.
5. Thesis writing and eventually paper writing for Conference.

The supervisor will provide the students with initial literature and help the students access stakeholders and initial data for the empirical investigation.

Appendix B

Extended Abstract ACM womENcourage 2022

Contains the extended abstract submitted by the authors, and accepted to the ACM womENcourage 2022 conference, held in Larnaka, Cyprus.

(Starts on the next page)

Investigating Digital support for inclusive, beautiful, climate neutral cities

FERDINAND WARD ÅDLANDSVIK, Norwegian University of Science and Technology, Norway
EIVIND SYRDALEN DOVLAND, Norwegian University of Science and Technology, Norway

The New European Bauhaus initiative calls on all of us to imagine and build together a sustainable and inclusive future that is beautiful for our eyes, minds, and souls. This project investigates the role of digital support for inclusive, beautiful, climate neutral cities. This abstract presents the project, the problem, some preliminary findings from relevant literature.

Additional Key Words and Phrases: inclusion, digital support, sustainability, climate, aestetics, beautiful, together

ACM Reference Format:
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1 INTRODUCTION

The New European Bauhaus initiative calls on all of us to imagine and build together a sustainable and inclusive future that is beautiful for our eyes, minds, and souls. Beautiful are the places, practices, and experiences that are:

- **Enriching**, inspired by art and culture, responding to needs beyond functionality.
- **Sustainable** in harmony with nature, the environment, and our planet.
- **Inclusive**, encouraging a dialogue across cultures, disciplines, genders and ages. [7]

Digital support will be necessary for this transition. The goal of this project is to investigating Digital support for inclusive, beautiful, climate neutral cities. This project will be connected to the COST Action CA19122 EUGAIN [3], Project CityxChange [2], the New European Bauhaus [6] and EU Project Craft [9].

The CrAFt project will place the transition to climate neutrality at the heart of urban stakeholders. The project is inspired by the impact model of the New European Bauhaus that helps cities to harness the value of inclusiveness, aesthetics and sustainability, as understood within the local contexts of their city, in their transformation towards climate neutrality, in at least 80 local emblematic projects.

The project will support the Mission Board on Climate-Neutral and Smart Cities in designing and deploying Climate City Contracts, based on experience-based knowledge from 3 Cities (Bologna, Prague and Amsterdam) and 70 Reference Cities engaged in testing and sharing knowledge together with cultural, artistic and creative sectors, property owners and tenants, and citizens and communities.

Our project is part of this community and will focus on Trondheim, Norway and its stakeholders.

2 RESEARCH QUESTION

The main aim for the project is to investigate how Digital support can contribute to supporting the development of the cities of the future. We want to investigate what kind of Digital support is already used, and if there is a

Manuscript submitted to ACM

correlation between Digital support and specific SDG's (Sustainable Development Goals). There are several research papers regarding the topic today, but we want to investigate deeper and more accurate into our specific problem. We want to know if, and in what sense, Digital tools can be used to move to the aim of "inclusive, beautiful, climate neutral cities", especially focused on Trondheim, Norway and its stakeholders.

3 LITERATURE REVIEW

The following section provides some relevant findings in the literature addressing the problems and possibilities towards the topic. The following excerpts might be influential for our further work.

A start on the way to reach the goal of future cities being inclusive and beautiful is to facilitate for, and include women in technology. The problem of diversity and inclusion in the area of Computer Science is significant, and specifically women are underrepresented in all levels of the discipline. The challenge of increasing the amount of women in this area has been identified for a long time, but progress have been slow and hard to measure across borders, companies and institutions. [5] Thirty years of research have revealed that sex and gender bias is socially harmful and expensive [4].

Digitalization has a direct impact on the society today, and influence peoples lives in a bigger and bigger sense, and therefore a lack of diversity in this field can unintentionally exclude populations. There is a need for diversion in the field, and to achieve this goal we need tools to facilitate for everyone to have successful careers [1].

A possible digital tool which can be used in this sense is Artificial Intelligence, which have grown, and continues to grow in a rapid pace. AI is expected to affect global productivity, equality and inclusion, environmental outcomes and several other areas.

The role of artificial intelligence in achieving the Sustainable Development Goals has been investigated in [8]. The paper claims that 67 targets (82%) within the Society group of the 17 SDGs could potentially benefit from AI-based technologies. For instance, in SDG 11 on sustainable cities, AI may act as an enabler for all the targets by supporting the provision of food, health, water, and energy services to the population. The Environment group (SDG 13,14 and 15) is found to be the highest scoring group, with 25 identified targets (93%) where AI could act as an enabler.

Although AI is found to be a possible enabler for many of the targets in the 17 SDGs, the research also found that it can have negative impact on the same goals. In the Society group 38% of the targets can be impacted negatively by AI, with 20% in the Economic group and 30% in the Environment group.

4 PRELIMINARY CONCLUSIONS AND FURTHER WORK

The literature indicates that there is a relation between inclusion and processes to achieve climate neutrality. Our work will concentrate on possibilities of implementing measures in order to reduce the problem and move in the right direction. The question is how we can use technology and digital tools in order to achieve this, and how we can do it in the best possible way to improve inclusion.

The literature reviewed is only a small fraction of the literature available on this growing area, but based on the findings it is clear that digital support is already contributing, and certainly could contribute even more to the aim of inclusive, beautiful, climate neutral cities in the future.

As stated earlier we will specifically focus on Trondheim and its stakeholders. We are going to interview the stakeholders, acquire data sets and analyze the knowledge to provide new knowledge about the interplay of digital support, climate neutrality and inclusiveness.

5 REFERENCES

REFERENCES

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[7] European Union. 2022. beautiful | sustainable | together. https://europa.eu/new-european-bauhaus/index_en The New European Bauhaus is a creative and interdisciplinary initiative that connects the European Green Deal to our living spaces and experiences..

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Appendix C

Focus Group Information Letter and Consent Form

This information letter and consent form aimed to offer comprehensive information about the research study, enabling participants to make an informed decision about their involvement. Additionally, the consent form served as an opportunity for participants to express their willingness to participate by providing their signature.

(Starts on the next page)

Information Letter

This is an information letter and consent form about your participation in a research project where the main purpose is to investigate how to design a mobile application to encourage citizen participation in smart sustainable cities. In this letter we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project

This master's project aims at investigating digital support for inclusive, beautiful and climate neutral cities. This project intends to investigate how a mobile application can be designed for citizens of Trondheim to actively participate towards a more sustainable and inclusive city.

Who is responsible for the research project?

The two master's students in Computer Science Ferdinand Ward Ådlandsvik and Eivind Syrdalen Dovland are responsible for the research project. The project is connected to the research group "Software for a better society" at The Department of Computer Science at the Norwegian University of Science and Technology.

What does participation involve for you?

In this focus group discussion, citizens of Trondheim are invited to reflect on what motivates them to actively participate towards a more sustainable and inclusive city.

Participation is voluntary

Participation in the project is voluntary. If you choose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you choose not to participate or later decide to withdraw.

Your personal privacy

We will not use any of your personal data in this project. All discussions are anonymous, and the audio will only be recorded for transcription purposes.

Yours sincerely,

Eivind Syrdalen Dovland

(Master's student)

Ferdinand Ward Ådlandsvik

(Master's student)

Consent form

I have received and understood information about the project and have been given the opportunity to ask questions. I give consent:

□ To participate in the focus group discussion.

Trondheim, Norway _____

06.03.2023 (signature)

Appendix D

Information Letter and Consent Form Usability Testing Iteration 1

This information letter and consent form aimed to offer comprehensive information about the research study, enabling participants of the Iteration 1 of usability testing to make an informed decision about their involvement. Additionally, the consent form served as an opportunity for participants to express their willingness to participate by providing their signature.

(Starts on the next page)

Information Letter

This is an information letter and consent form about your participation in a research project where the main purpose is to investigate how to design a mobile application to encourage citizen participation in smart sustainable cities. In this letter we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project

This master's project aims at investigating digital support for inclusive, beautiful and climate neutral cities. This project intends to investigate how a mobile application can be designed for citizens of Trondheim to actively participate towards a more sustainable and inclusive city.

Who is responsible for the research project?

The two master's students in Computer Science Ferdinand Ward Ådlandsvik and Eivind Syrdalen Dovland are responsible for the research project. The project is connected to the research group "Software for a better society" at The Department of Computer Science at the Norwegian University of Science and Technology.

What does participation involve for you?

In this user test, members of the USES research group are invited to usability test a mobile application prototype, and answer a questionnaire and some interview questions.

Participation is voluntary

Participation in the project is voluntary. If you choose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be deleted. There will be no negative consequences for you if you choose not to participate or later decide to withdraw.

Your personal privacy

We will not use any of your personal data in this project. All collected data is anonymous, and the audio will only be recorded for transcription purposes.

Yours sincerely,

Eivind Syrdalen Dovland

(Master's student)

Ferdinand Ward Ådlandsvik

(Master's student)

Consent form

I have received and understood information about the project and have been given the opportunity to ask questions. I give consent:

□ To participate in the usability testing of the prototype.

Manaus, Brazil _____

17.04.2023 (signature)

Appendix E

Information Letter and Consent Form Usability Testing Iteration 2

This information letter and consent form aimed to offer comprehensive information about the research study, enabling participants of the Iteration 2 of usability testing to make an informed decision about their involvement. Additionally, the consent form served as an opportunity for participants to express their willingness to participate by providing their signature.

(Starts on the next page)

Information Letter

This is an information letter and consent form about your participation in a research project where the main purpose is to investigate how to design a mobile application to encourage citizen participation in smart sustainable cities. In this letter we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project

This master's project aims at investigating digital support for inclusive, beautiful and climate neutral cities. This project intends to investigate how a mobile application can be designed for citizens of Trondheim to actively participate towards a more sustainable and inclusive city.

Who is responsible for the research project?

The two master's students in Computer Science Ferdinand Ward Ådlandsvik and Eivind Syrdalen Dovland are responsible for the research project. The project is connected to the research group "Software for a better society" at The Department of Computer Science at the Norwegian University of Science and Technology.

What does participation involve for you?

In this user test, citizens of Trondheim are invited to user test a mobile application prototype, and answer a questionnaire and a few interview questions.

Participation is voluntary

Participation in the project is voluntary. If you choose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be deleted. There will be no negative consequences for you if you choose not to participate or later decide to withdraw.

Your personal privacy

We will not use any of your personal data in this project. All collected data will be anonymized. We will do video and audio recording of the usability test, both for transcription and to help observe how you interact with the application.

Yours sincerely,

Eivind Syrdalen Dovland

(Master's student)

Ferdinand Ward Ådlandsvik

(Master's student)

Consent form

I have received and understood information about the project and have been given the opportunity to ask questions. I give consent:

□ To participate in the usability testing of the application.

□ To the use of a picture of myself conducting the usability test to be used in our master's thesis

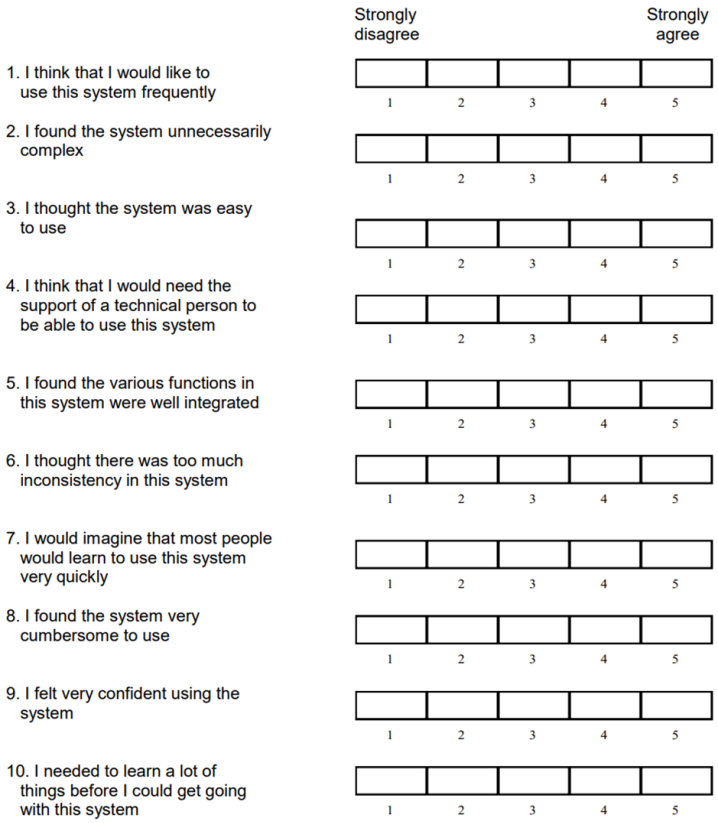
Trondheim, Norway _____

09.05.2023 (signature)

Appendix F

System Usability Scale

System Usability Scale



Appendix G

Notification Form NSD

This document includes the submitted and assessed application to NSD, confirming that the authors possesses the capability to conduct the research.

(Starts on the next page)

Sikt

Notification Form

Reference number
545027

Which personal data will be processed?

- Name (also with signature/written consent)
- Date of birth
- Email address, IP address or other online identifier
- Photographs or video recordings of people
- Sound recordings of people
- Background data that can identify a person

Describe which background data that can identify individual persons you will be processing

Kjønn, alder, yrke og utdanning. Vi ønsker å spørre om hvor personene holder til (i eller utenfor by).

Lydopptak for transkribering av brukertest (vil anonymiseres og slettes)
Video av brukertest, kun ved samtykke

Project information

Project title

Investigating digital support for for inclusive, beautiful, climate neutral cities

Project description

The purpose of the project is to investigate the current status of digital support in the work for the New European Bauhaus initiative.

We will:
1. Run a systematic literature review of the theme

2. Plan an empirical investigation

3. Run an empirical investigation (data collection, data analysis), like for example interviews with stakeholders in the above projects and/or analysis of existing data sources such as videos, blogs, magazines.

4. Propose new information sources which address gender and diversity

5. Thesis writing and eventually paper Writing for Conference

The supervisor will provide the student(s) with Initial Literature and help the student(s) to access to Stakeholders and initial data for the Empirical Investigation.

If the project will be run as a 15 + 30 project, I expect that during the Autumn semester the student(s) will implement steps 1 and 2 and during Spring Semester steps 3,4,5.

Explain why it is necessary to process personal data in the project

Vi ønsker å vite hvordan innbyggere forstår sammenhengen mellom klima, inkludering og kunst i byer, og hvorfor akkurat denne sammenhengen er viktig for fremtidens byer. I dette arbeidet er enkelte personopplysninger relevante for å bedre forstå og analysere den innhentede dataen. Vi ønsker å samle inn informasjon gjennom brukertestintervjuer, der vi observerer og stiller spørsmål til brukere som tester en prototype.

Project description

oppgavebeskrivelse.png

External funding
Ikke utfyllt
Type of project
Student project, Master's thesis

Contact information, student
Eivind Syrdalen Dovland, eivindsd@stud.ntnu.no, tlf: +4747829669

Data controller

Data controller (institution responsible for the project)
Norges teknisk-naturvitenskapelige universitet / Fakultet for informasjonsteknologi og elektroteknikk (IE) / Institutt for datateknologi og informatikk

Project leader (academic employee/supervisor or PhD candidate)
Letizia Jaccheri, letizia.jaccheri@ntnu.no, tlf: 73593469

Will the responsibility of the data controller be shared with other institutions (joint data controllers)?
No

Sample 1

Describe the sample

Innbyggere i Trondheim. Mer spesifikt ønsker vi å bruke personer i bedrifter med spesifikt ansvar for bærekraft/klima og/eller inkludering. Vi ønsker også å bruke personer med interesse for miljø, og av praktiske årsaker vil studenter prioriteres.

Describe how you will recruit or select the sample

Skal bruke nettverket på NTNU til å finne intervjuobjekter, og forsøke å få et aldersmessig balansert utvalg intervjuobjekter. Har gjennom veileder mange potensielle kontakter.

Age
18 - 70

Personal data relating to sample 1
- Name (also with signature/written consent)
- Date of birth
- Email address, IP address or other online identifier
- Photographs or video recordings of people
- Sound recordings of people
- Background data that can identify a person

How will you collect data relating to sample 1?
Personal interview

Attachment

User Test Guide (4).pdf

Legal basis for processing general categories of personal data
Consent (General Data Protection Regulation art. 6 nr. 1 a)

Other

Describe

Brukertest av prototype. Utvalget vil teste funksjonalitet, interaksjon og forståelse av innholdet i prototypen. Det vil være en testansvarlig som har ansvaret for å observere og veilede under brukertesten, og resultatene vil bli registrert og beskrevet anonymisert. Guide for brukertesten er lastet opp under "Personlig intervju", for å få lagt ved denne guiden. Kunne vært fint å ha muligheten til å laste opp dokumenter også under "Annet".

Legal basis for processing general categories of personal data

Consent (General Data Protection Regulation art. 6 nr. 1 a)

Online survey

Attachment

Questionnaire Guide.pdf

Legal basis for processing general categories of personal data
Consent (General Data Protection Regulation art. 6 nr. 1 a)

Information for sample 1

Will you inform the sample about the processing of their personal data?
Yes

How?
Written information (on paper or electronically)

Information letter

information_letter_updated.pdf

Third Persons

Will you be processing data relating to third persons?
No

Documentation

How will consent be documented?

- Manually (on paper)

How can consent be withdrawn?

Ta kontakt med Letizia Jaccheri (letizia.jaccheri@ntnu.no)

How can data subjects get access to their personal data or have their personal data corrected or deleted?

Ta kontakt med Letizia Jaccheri (letizia.jaccheri@ntnu.no)

Total number of data subjects in the project
1-99

Approvals

Will you obtain any of the following approvals or permits for the project?
Ikke utfyllt

Processing

Where will the personal data be processed?

- Computer belonging to the data controller
- External service or network (data processor)

Who will be processing/have access to the collected personal data?

- Project leader
- Student (student project)
- Data processor
- Internal co-workers

Which data processor will be processing/have access to the collected personal data?

Microsoft OneDrive benyttes til lagring av intervjuene og brukertestene, og Microsoft Teams benyttes til gjennomføring. NTNU har en databehandleravtale med Microsoft, og alle tjenestene er beskyttet med passord. Vi transkriberer intervjuene selv og er de eneste med tilgang til intervjuopptakene.

Will the collected personal data be transferred/made available to a third country or international organisation outside the EU/EEA?
No

Information Security

Will directly identifiable data be stored separately from the rest of the collected data (e.g. in a scrambling key)?
Yes

Which technical and practical measures will be used to secure the personal data?

- Personal data will be anonymised as soon as no longer needed
- Restricted access

Duration of processing

Project period
01.12.2022 - 31.12.2023

What happens to the data at the end of the project?
Personal data will be anonymised (deleting or rewriting identifiable data)

Which anonymization measures will be taken?

- Any sound or video recordings will be deleted
- Personally identifiable information will be removed, re-written or categorized
- The identification key will be deleted

Will the data subjects be identifiable (directly or indirectly) in the thesis/publications from the project?
No

Additional information

NTNU

Norwegian University of
Science and Technology