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CO-DESIGNING A MOBILE APPLICATION FOR SUSTAINABLE MOBILITY IN SMART CITY

A gamified resolution to gain the commitment of users

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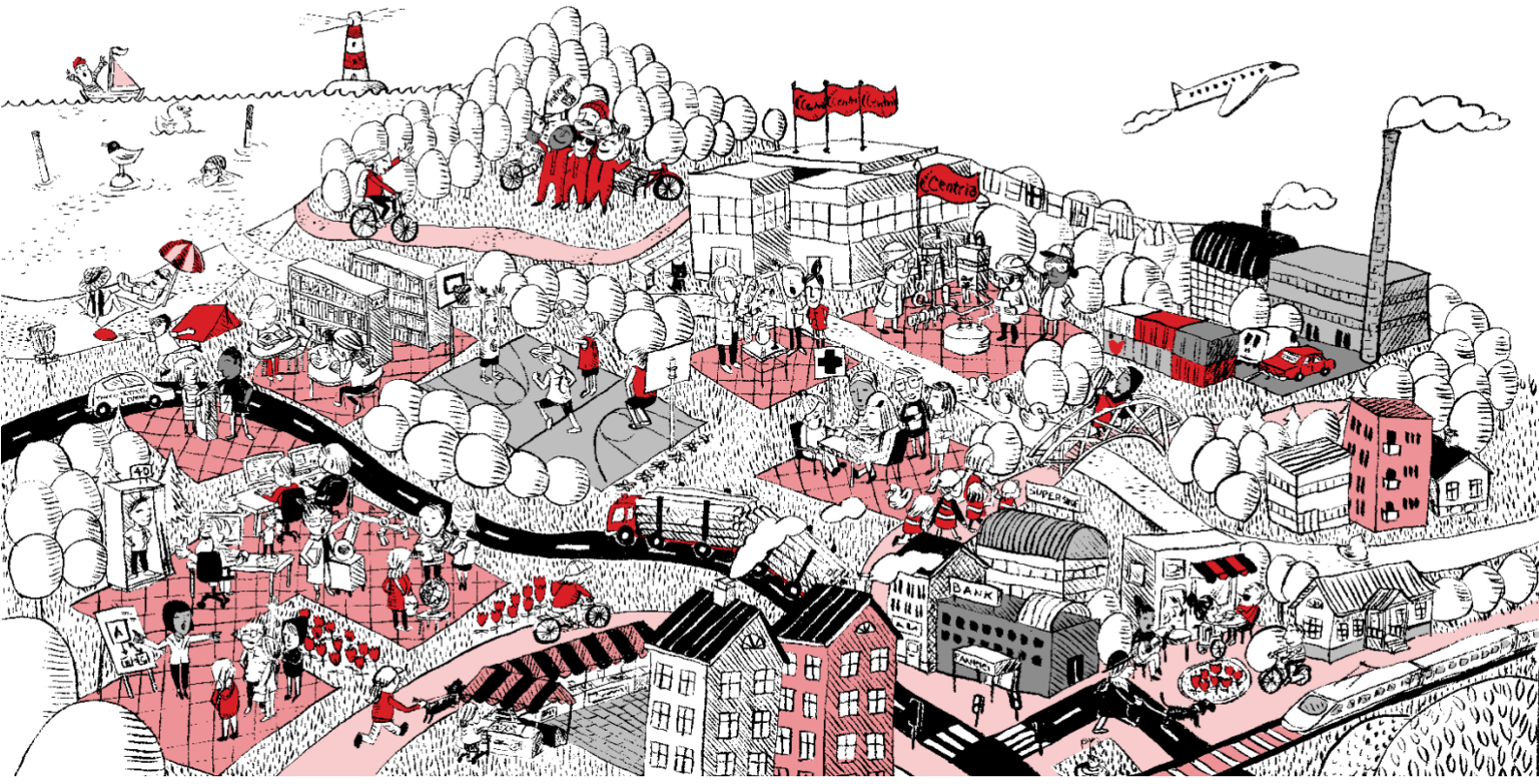

ABSTRACT

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During the pandemic, the National Council on Climate and Air Quality of Korea promoted "Innovation 4 Blue Skies (I4BS)" to foster climate technology innovators to strengthen the national potential to solve delicate dust/climate change problems would join young innovators in Asia. The program genuinely inspired the author. Based on the older concept designed by the author and her team, the thesis was believed to be an excellent renovation to enhance the air quality through sustainable mobility, which focuses more profoundly on the user interface and experience.

The thesis aimed to design a mobile application that contributes to decreasing carbon emissions or maintaining the current low-carbon emissions level attributed to the COVID-19 outbreak, increasing climate resilience, decreasing particulate matter, or maintaining the current level of low-particulate matter concentration levels attributed to the COVID-19 outbreak.

The thesis applied various approaches, including co-design and gamification, to the user experience design for a specific concept, herein a mobile application, to gain users' commitment. By exploring and defining the needs and user's demographic, the author designed a mobile application prototype and delivered it to a specific group of users to gain feedback to refine and modify the design iteratively.

The application takes the user's location and other attributes, e.g., gender and age, on registration. It then sends the user pollution warnings when the air pollutants are predicted to be directed towards the user's country of residence. Further, the application structure is based on a rewards-based system wherein the coupons and other promotions are credited to the account. The idea of crediting a user's account on pollution alert is that if the user can see the benefits they could redeem, simply a touch away – they would be more incentivized to adopt more eco-friendly practices to redeem them. The redemption solely occurs after the application verifies that the user has diminished their carbon emission levels. The application restricts a reduction of at least 10 percent from the original carbon emission levels.

Key words
environmental, gamification, mobile application design, public transportation, sustainability

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Finally, I am genuinely fortunate to have my mothers Thuý Diệu and Má Bảy, always supporting me through years of studying. Also, I would like to thank my big family and friends in Vietnam, Finland, and Taiwan for supporting my study and offering me emotional and moral comfort.

Kokkola, May 13, 2021

Ngoc Nguyen

CONCEPT DEFINITIONS

API

Application Programming Interface

EMM

Empathy Map Method

IT

Information Technology

MVP

Minimum Viable Product

UI

User Interface

UX

User Experience

TABLES

1 INTRODUCTION

During the coronavirus outbreak, some of the world's most polluted cities have experienced improved air quality due to reduced social and economic activities. Sometimes the source of air pollution in a region is in another region or country. Flowing air can carry the particulate matters along with it from the originating region to entirely different regions causing people to get affected by the actions of other countries. Concerning carbon emission, extensive usage of personal vehicles contributed to the rise of carbon emission from an individual level. This causes various threats to the environment, other species, and a healthy lifestyle.

However, as countries worldwide are lifting their lockdown measures and reopening their economy, the air quality is expected to become polluted once again.

> People who have recovered from COVID-19: As their lungs are still weak, they need to stay protected from air pollution to avoid chances of infection. [...] Over 7.58 million people had recovered from the disease. (Elflein, 2021.)

The other target audience of the thesis is public transport and e-commerce sites. By using the application API, these companies may run promotions and offer reward points for using their services. Southeast Asia is supposed to be the promising area first to launch the application. For instance, they are looking for innovative solutions to over-crowding due to Asia's public transport systems limit social distancing (Maslog 2020). Specifically, the Ho Chi Minh City (Vietnam) bus service fails to attract more passengers despite increased subsidy (Nguyen 2020). However, the application is expected to be highly scalable based on global data. Thus, it does not discriminate against users based on culture, gender, or age.

This thesis presents an idea of designing a mobile application to encourage the user to engage in a greener means of transportation with the help of gamification and thorough research of people's needs and behavior, and the co-designing technique. The thesis will cover the theoretical aspect of terms, ideas, and design processes such as gamification, intelligence, sustainable mobility, and co-design. In terms of predicting airflow particle direction, if the application can do that and a hazardous area falls into the airflow path, it can alert users who are falling on the airflow path. The final product must reward users for helping them stay motivated to lower their daily carbon emission level to as minimum as possible. When users

get a pollution alert, the author aimed to increase users' motivation to keep individual level carbon emission at the lowest possible value.

The structure of this thesis comprises four parts: introduction, literature review, co-designing a mobile application, discussion, and conclusion. Part 1 (introduction) outlines the background, motivation, objective and research question, research approach, and thesis structure. Part 2 (literature review) clarifies the definition of co-design, sustainable mobility in smart cities, gamification, and user experience evaluation. Also, it investigates the rationale, procedure, case of the term in the context of the thesis, and introduces frameworks to be used within the thesis. Part 3 (co-designing a mobile application) includes four sections parallel four phases in a co-design process: discover, define, develop, and deliver. In part 4 (discussion and conclusion), the author reflected the gamified application in practice. The limitations and future research of this thesis are also articulated. Eventually, the chapter presents the implications and conclusion.

2 LITERATURE REVIEW

There is a thriving discussion of co-design concerning social and community services, for example, in the public and civil society. Consequently, the million-dollar worth question "does co-design lead to greater social impact" remains unanswered (FIGURE 1) (Burkett, 2012.) The public sector will be discussed in detail within this thesis, especially about sustainable mobility in a smart city. The corresponding design process is designed and delivered by service providers – such as the application developers/providers and public transport organizations. Hence, it certainly generates an impact on citizens. The product, which is created with the active participation of both stakeholders and users, has a higher possibility of meeting the end-user's needs and contributing to their well-being.

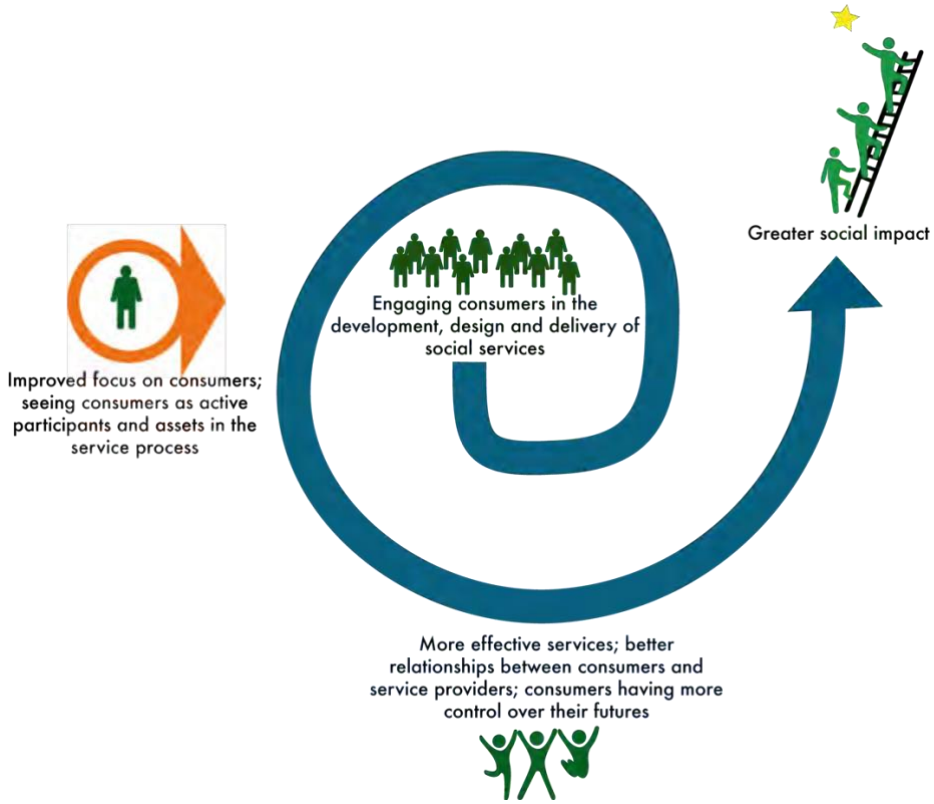

FIGURE 1. Greater social impact replaces greater market share and profits (adapted from Burkett, 2012)

2.1 Co-design

In this section, co-design will be addressed by going through the term definition, the rationale of choosing co-design for the thesis, its procedure, and its benefits.

2.1.1 The definition of co-design

The work of the thesis is organized as a co-design process. The original term co-design is collaborative design or participatory design, of which the innovation process involving non-designers such as customers, partners, and end-users (Chesbrough 2003; Kujala 2003; Rohracher 2005; Chesbrough et al. 2006; Edvardsson, Gustafsson, Kristensson, Magnusson, Matthing 2006). Co-design is described as a process of creative cooperation rather than a design style nor concept. It comprises various methodologies, ranging from research-oriented ones to design-oriented ones, focusing on user involvement, such as applied ethnography and generative tools. It may range from approaches in which researchers and designers move toward users, i.e., usability testing, to approaches in which users move toward researcher and designers, i.e., participatory design. (Sanders & Stappers 2008, 5-18; Steen 2011, 45-60.)

> Co-Designing: collaborating, including and designing WITH people that will use, deliver or engage with a service or product (Burkett 2012, 4.)

2.1.2 Rationale

The thesis deliberately concentrates on the user experience; hence, this approach is chosen to ensure the result meets the end users' needs innovatively and is usable (Mitchell, Ross, Sims, Parker 2015, 205-220; Trischler, Pervan, Kelly, Scott 2017, 75-100). Bucciarelli (1994) argued that design should be always co-design because it is inherently a social process whilst another definition is provided by Kleinsmann and Valkenburg (2008, 369-86), drawing attention to the sharing and combining of knowledge from different disciplines and to achieving the larger common objective which is the new product to be designed. Corresponding to Kleinsmann et al., co-design can be understood and organized as a process of collaborative design thinking or joint inquiry and imagination (Steen 2013, 18). For instance, the contributors can provide

information and inspiration, evaluate ideas and prototypes, think about new solutions, predict their future behavior with the product, and provide new design directions (van Rijn, H., and Stappers, P.J. 2008, volume 8, 178).

2.1.3 Procedure

In design thinking, especially in this thesis, problems and possible solutions are developed and evaluated simultaneously in an iterative process – a "design process involves finding as well as solving problems" so that "problem and solution co-evolve" (Lawson 2006, 125; Cross 2006, 80). The co-design application will benefit every user involved by increasing the user's psychological ownership feeling when experiencing the product. Ownership can serve as intrinsic motivation for users to be involved in the design and simultaneously increase data value. (van Rijn, H. et al. 2008, 178-81.) In participatory design, Wang et al. (2006) define three motives to feel ownership that can make users feel that they own the results and process: instrumental, perceptive, and symbolic (FIGURE 2).

FIGURE 2. The relations between the three motives, psychological ownership and motivation for involvement in the design process (adapted from Wang et al 2006)

There is a wide range of variety in selecting methods to involve people in collaborative design. It depends on the design process stage and the service users' context with whom the service providers work. An overview of four stages in the design process, sorted into generative research part and developmental design part, will visualize the actual process the thesis will follow (FIGURE 3).

2.1.4 Benefits

The process commences by encouraging users to express themselves employing tools and techniques, e.g., making tangible artifacts, giving verbal and written explanations (instrumental). Then, users can receive authorship due to their expressions in results

(perceptive). In the last stage of the process, the results reflect the retained users' input to show their contributions were valued and understood (symbolic). (Wang et al. 2006.)

Not only do the service's customers gain benefits from the co-design process, but the service design project and the organizations also do so. A wide range of advantages comprises advancing the creative process, developing better service definitions, organizing the project more efficiently, and enhancing customers' or users' loyalty. Organizations can also yield benefits from this process related to the organizing co-design during a design project, not to the benefits of providing (better) services. For example, an organization can foster creativity or extend its capabilities to innovate. (TABLE 1) (Steen, Manschot, Koning 2011, 53-60.)

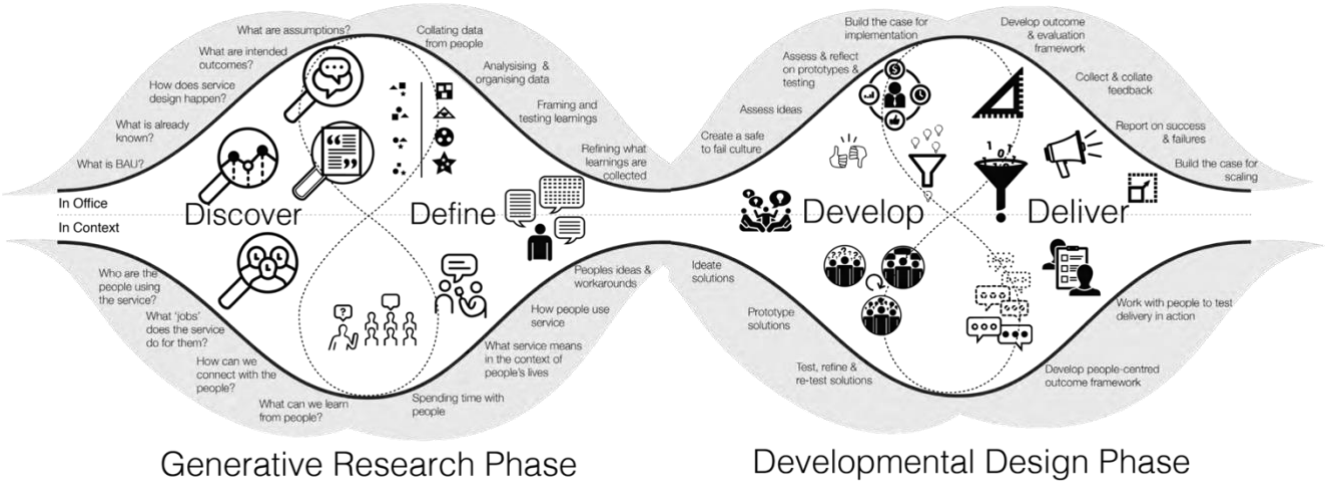

FIGURE 3. Four stages in the design process, and the sorts of activities that relate to each if designers embed co-design into the process (adapted from The Australian Centre for Social Innovation)

2.2 Sustainable mobility in smart city

In this section, sustainable mobility in the smart city will be discussed by examining the term definitions of sustainable mobility and smart city, respectively — the case of sustainable mobility and smart city in the scope of the thesis.

2.2.1 The definition of sustainable mobility

It is a fact that the transport system performs vital services for the community by moving people and goods based on actual user demand, i.e., traveling in individuals' spare time. For instance, the transport sector in Finland represents more than 10 percent of the gross domestic product and an equivalent share of employment (Vartiainen 2012). It is consequently impossible to stop transporting or moving; however, there is always a more innovative and sustainable way to accomplish the mobility demands. This thesis will not encompass renewable energy or ultra-efficient vehicles but deliberate on convincing people and the commercial sector to make sustainable choices and create a healthier lifestyle when using transport.

General transport analysis is based on the proposition that travel is a cost and that travel times should be as short as possible. In contrast, travel patterns have been changing, and there is an increment in leisure-based travel; travel time may become more of a positively valued activity (Loo & Chow 2006; Schlich et al. 2004; Mokhtarian et al. 2006). Hence, the concepts of using mobility should be taken under reflection – the rationale for people's travel and how they handle time. The co-design process's approach with relevant stakeholders' engagement will help the author understand the pattern and suggest optimal explications (Banister 2008).

2.2.2 The definition of smart city

Cities are both places of opportunity and diseases. During the latest sixty years, city dimensions have been growing progressively worldwide. Dameri (2014, 45-88) stated that by 2050, 70 percent of the population would live in cities. Mobility is a significant facility to support the urban area's functioning (Staricco 2013, 289-354). Consequently, the smart city is supposed to be a promising urban tactic using technology to increase the quality of life in urban

space, improving environmental quality, and delivering better services to the citizens (Hall 2000, 633-649). This thesis is expected to reason about how sustainable mobility interacts reciprocally with smart cities, how it impacts almost all the city stakeholders' life quality, and how much it can effectively solve the urban problems.

TABLE 1. Benefits of co-design in service design projects (adapted from Steen et al 2011, 58)

Benefits for the service design project	*Benefits for the service's customers or users*	*Benefits for the organization(s)*
Improving idea generation:		
• **Better ideas**, e.g. from customers or users M; Cases A and B, with high originality and user value KMM • **Better knowledge about customers' or users' needs** R&S; M, e.g. changing existing views or validating ideas or concepts Case A • **Better idea generation**, e.g. by bringing together customers, users and employees S;C&L; P&H; M; R&S		• **Improved creativity** M; R&S; Case B • **Improved focus on customers or users** B and, e.g. better dissemination of findings about customers' or users' needs Case A • **Better cooperation between** different people or organizations, and across disciplines B; M; Case C
Improving the service:		
• **Higher quality of service definition** K; Case C • **More successful innovations,** e.g. reduced product failure risk H	• **Better fit** between service and customers' or users' needs, and better service experience K; H; Case A • **Higher quality of service** K; R&S; Case C • **More differentiated service** A	
Improving project management:		
• **Better decision making**, e.g. quality and speed R&S • **Lower development costs** R&S • **Reduced development time or time-to-market** A; H; R&S • **Continuous improvements** H		
Improving longer-term effects:		
	• **Higher satisfaction** of customers or users K; R&S • **Higher loyalty** of customers or users R&S • **Educating users** A	• **More successful innovations**, e.g. rapid diffusion A • **Improved innovation** practices, processes and capabilities B; R&S • **More support and enthusiasm** for innovation and change B • **Better relations** between service provider and customers A; H • **Better public relations** A

Note: ᴬAlam, 2002; ᴮ Burns et al., 2006; C&L Cottam & Leadbeater, 2004; ᴴ Hoyer et al., 2010; KMM Kristensson, Magnusson & Matthing, 2002; Magnusson, 2003; Magnusson, Matthing & Kristensson, 2003; Kristensson & Magnusson, 2010; ᴹ Muller, 2002; P&H Parker & Heapy, 2006; R&S Roser & Samson, 2009; ˢ Sanders, 2000; Sanders, 2002.

2.2.3 Case of sustainable mobility and smart city in the thesis

Cities are both places of opportunities and diseases. During the latest sixty years, city dimensions have been growing more and more worldwide. Dameri (2014, 45-88) stated that

by 2050, 70 percent of the population would live in cities. Mobility is a significant facility to support the urban area's functioning (Staricco 2013, 289-354). Consequently, the smart city is supposed to be a promising urban tactic using technology to increase the quality of life in urban space, improving environmental quality, and delivering better services to the citizens (Hall 2000, 633-649). This thesis is expected to reason about how sustainable mobility interacts reciprocally with smart cities, impacts almost all the city stakeholders' life quality, and how much it can effectively solve the urban problems.

The term smart city is described as "a city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of activities of self-decisive, independent and aware citizens" (Giffinger, Fertner, Kramar, Kalasek, Pichler-Milanović & Meijers 2007). In the scale of the thesis, the author defined a city as smart when it is committed to the implementation of sustainable mobility in which technology is the instrument as the final aims are to improve the citizens' quality of life and to competently manage natural resources (Benevolo, Dameri, D'Auria 2016, 13-28). From the literature analysis, the thesis's final product attempts to perform the following five characteristics. (FIGURE 4)

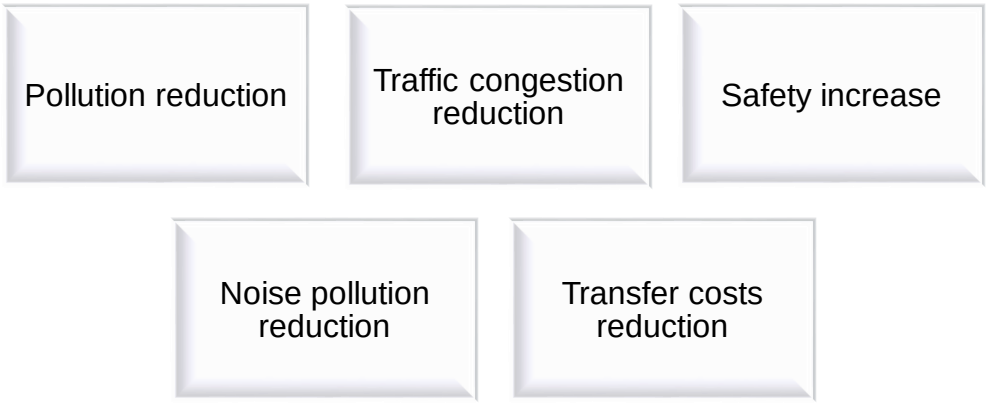

FIGURE 4. Five important objectives of the thesis’s product

2.3 Gamification

The author intended to use this section to introduce the gamification definition, its employment, and the Octalysis framework.

2.3.1 The definition of gamification

Gamification is a human-focused design that optimizes humans in the system instead of the function-focused design, which is the system's pure efficiency.

> Gamification is the craft of deriving all the fun and addicting elements found in games and applying them to real-world or productive activities (Chou 2015, 8.)

Gamification is an approach stemming from the domain of game design. Practicing such incentive mechanisms can positively enrich products, services, and information systems with game-design elements to positively influence users' motivation, productivity, and behavior. (Deterding et al. 2011, 10-12; Huotari & Hamari 2012, 19-20.)

2.3.2 Gamification employment

The employment of gamification may not describe games in the decorous meaning of the term. In lieu, they utilize information technology possibilities to develop motivation concepts, which continuously engage users in using products, services, and information systems (Blohm and Leimeister 2013, 275). This persuasive technology encompasses the design of gamified service bundles, such as a core offer (a product, a service, or an information system) and an IT based, gamified enhancing service for the core offer (Petkov et al. 2011, 2; Leimeister 2012; Huotari et al. 2012, 19-20). The major prevailing trend of gamification has played a principal role for CIOs (abbreviated form of Chief Information Officers) and IT planners (Gartner 2012, 4). Since 2015, 40 percent of the world's largest 1,000 organizations have been expected to implement gamification for transforming their business operations (Blohm and Leimeister 2013, 275).

Such specific usage objectives, which are the starting point for designing gamified enhancing services, could be derived from analyzing historical user behavior and describing how core offer providers wish their core offer to be used in the future. Huotari et al. (2012, 19-20) state that "these objectives are translated into appropriate game-design elements that are compiled into gamified enhancing services," thereby improving services strive to activate individual user motives regarding the core offer (FIGURE 5) (APPENDIX 1).

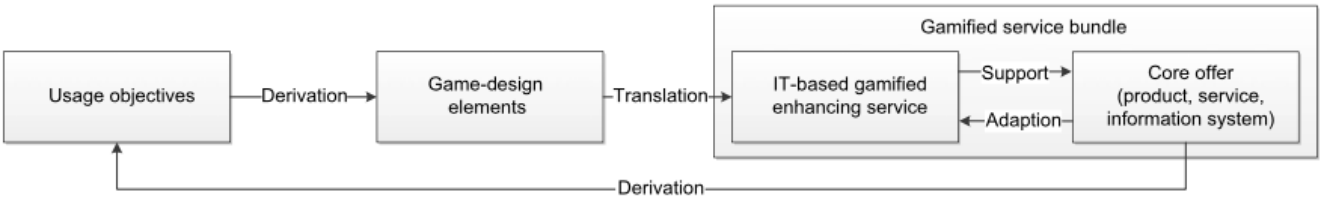

FIGURE 5. Gamification as design approach (adapted from Blohm et al. 2013, 276)

2.3.3 Octalysis framework

The gamification framework called Octalysis was introduced to analyze and build strategies around the various systems that make the game interesting based on specific Core Drives motivating users towards certain activities (FIGURE 6) (Chou 2015). There are 5 out of 8 core drives of gamification being examined in the book (intrinsic motivation), and an add-on feature (extrinsic motivation) – the Points, Badges, and Leaderboards (PBLs), that the thesis author would like to use in the mobile application design. The following parts of the thesis will dive deeper into these corresponding core drives: Epic Meaning & Calling (Chou 2015, chapter 5), Development & Accomplishment (Chou 2015, chapter 6), Ownership & Possession (Chou 2015, chapter 8), Social Influence & Relatedness (Chou 2015, chapter 9), Unpredictability & Curiosity (Chou 2015, chapter 11).

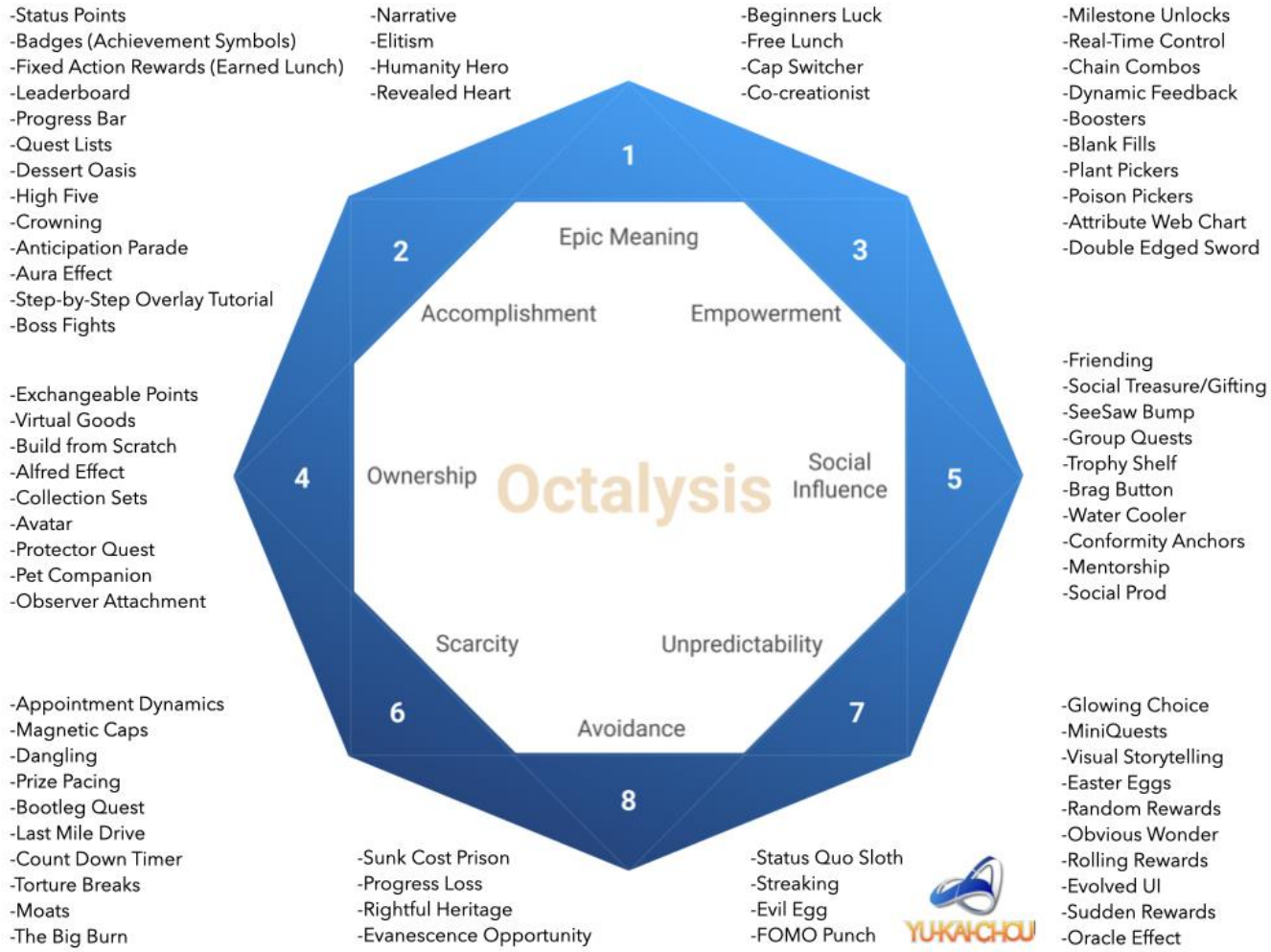

FIGURE 6. The Gamification Framework called Octalysis (adapted from Chou 2015)

Epic Meaning & Calling works as the first core drive when people suppose they are producing something greater than themselves and/or were "chosen" to take action. Another internal drive for making progress, advancing skills, accomplishing mastery, and ultimately overcoming challenges is Development & Accomplishment. This core drive is coincidently where most PBLs typically concentrate; however, a badge without a challenge is not meaningful. Ownership & Possession are expressed when users are motivated because they believe they own or control something, thereby innately tending to increase and improve what they own, such as virtual assets or virtual currencies within systems and customized profiles or avatars. An indispensable core drive nowadays is core drive 5 – Social Influence & Relatedness. It consolidates all the social elements that motivate people, including mentorship, social acceptance, social feedback, companionship, and even competition and jealousy. The last core that the author would employ for the application design is Unpredictability & Curiosity. It is firmly engaged because "when something does not fall into your regular pattern recognition

cycles, your brain kicks into high gear and pays attention to the unexpected." (Chou 2015, 25-28).

2.4 User experience evaluation

The last section of chapter 2 reviews the user experience evaluation definition, categorizes UX, usability, and accessibility. It is a good practice to understand what should be measured during the evaluation.

2.4.1 The definition of user experience (UX)

User experience (UX) is a buzzword in the last decade and its research has produced a multitude of UX models and frameworks. It is claimed that product development is the next level of competition, and no longer only about implementing features and testing their usability but about designing products that are enjoyable and support fundamental human needs and values (Nokia Corporation, 2005; Seidel, Loch and Chahil 2005, 439-449). UX definitions agree that it is more than just a product's usefulness and usability, and stress that UX is affected by the user's internal state, the context, and perceptions of the product. It is claimed as the subjective nature of UX. (Alben 1996, 11-15; Hassenzahl & Tractinsky 2006, 91-97; Mäkelä and Fulton Suri 2001, 19-22.) However, there is a gap between the research community and the product developers' understanding of the defintion of UX and UX evaluation (FIGURE 7).

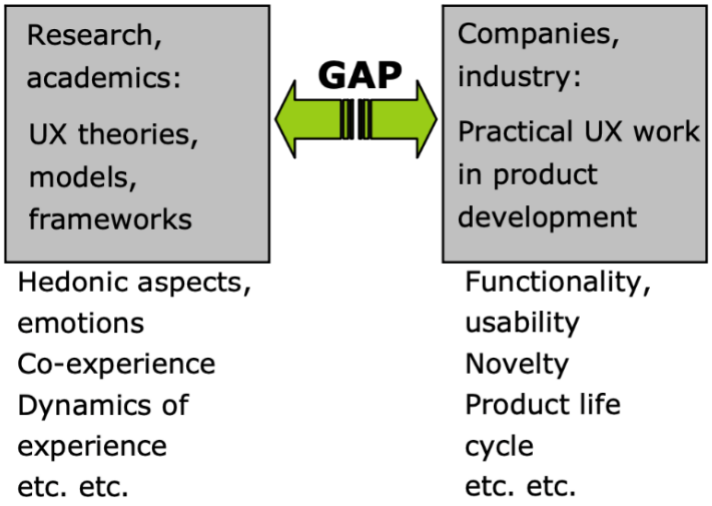

FIGURE 7. Currently the academic UX research and industrial UX development are focusing on different issues (adapted from Väänänen-Vainio-Mattila, Roto and Hassenzahl 2008, 19)

2.4.2 UX – Usability – Accessibility

Measuring UX, usability or accessibility should be prioritized. Therefore, understanding the differences between these terms will help the designer which methods should be used and what should be measured. Usability is variously interpreted as good user interface design (ISO 9126-1), an easy-to-use product (e.g., Cockton, 2004), good user performance (e.g., Väänänen- Vainio-Mattila et al, 2008), good user performance and satisfaction (e.g., ISO 9241-11), or good user performance and user experience (e.g., ISO 9241-210). Accessibility refers to product capabilities or a product usable by people with disabilities (e.g., ISO 9241-171).

Based on the two most common measures – summative measures and formative measures, and the two levels at which the measures of usability can be taken – the user interface level and the system level, Bevan (2009, 17) suggests a framework showing how measures of system usability and UX are dependent on product attributes. The framework shows how usability and UX relate to more considerable effectiveness, efficiency, satisfaction, accessibility, and safety (TABLE 2). Following the framework will benefit the selection of appropriate measures.

There are several types of measures of usability and UX. UX can be measured as the user's satisfaction with achieving a complete perception of users' needs and obtaining pragmatic and hedonic goals and pleasure. (Bevan 2009, 13.)

> Working with UX evaluation is a double task: We have to *understand* UX and make it *manageable* and *measurable*. (Mäkelä et al. 2001, 21)

TABLE 2. Factors contributing to system usability and UX

Quality characteristic	UX	Functionality	User interface usability	Learnability	Accessibility	Safety
Product attributes	Aesthetic attributes	Appropriate functions	Good UI design (easy to use)	Learnability attributes	Technical accessibility	Safe and secure design
UX pragmatic do goals	To be effective and efficient					
UX hedonic be goals	Stimulation, identification and evocation					
UX: actual experience	Visceral	Experience of interaction				
Usability (= performance in use measures)	Effectiveness and Productivity in use: effective task completion and efficient use of time			Learnability in use: effective and efficient to learn	Accessibility in use: effective and efficient with disabilities	Safety in use: occurrence of unintended consequences
Measures of UX consequences	Satisfaction in use: satisfaction with achieving pragmatic and hedonic goals					
	Pleasure	Likability and Comfort				Trust

2.4.3 What should be measured

The determination of suitable UX measures would be simplified when the designer can recognize and classify the different UX aspects, of which interpretations are several more than those of usability. Accustomed to Bevan's work, the thesis author visualized the checklist of what should be measured in a systems development environment (FIGURE 8).

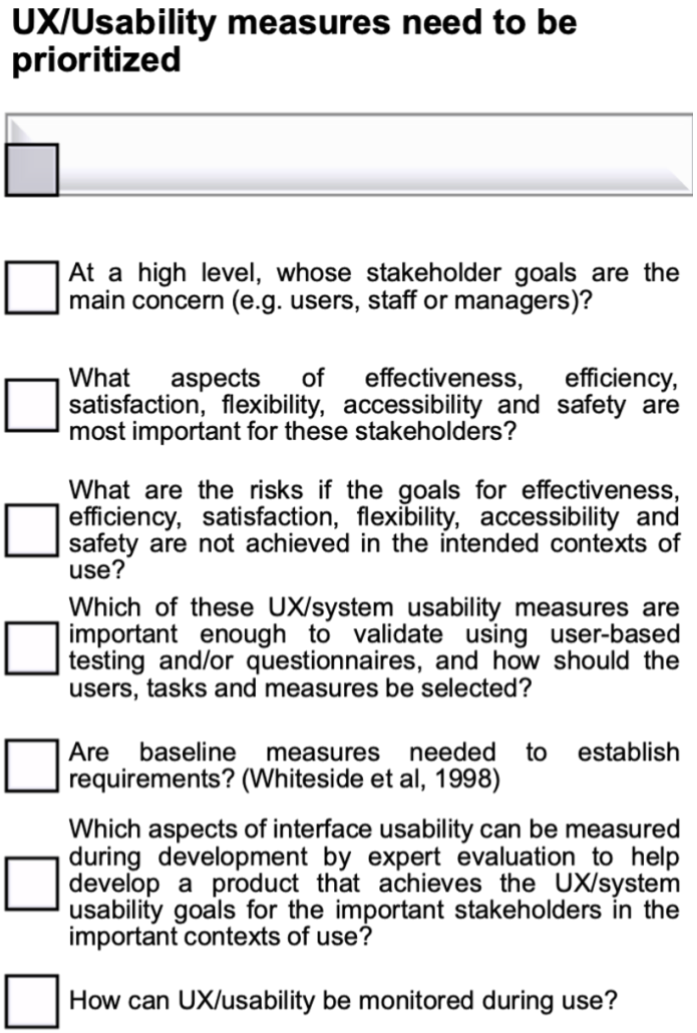

FIGURE 8. Checklist of what should be measured in a systems development environment (adapted from Bevan 2009)

3 CO-DESIGNING A MOBILE APPLICATION

A co-design process is used in this thesis by reflecting on and integrating the co-design approaches (discussed in section 2.1 Co-design). This part comprises four stages, being the "Explore and Define" section, the "Ideate" section, the "Prototype and evaluation" section, and the "Deliver" section. These stages are interdependent and ideally conveyed in an iterative process.

3.1 Discover and Define

In this section, the co-design approach, the defined user groups in co-design, and the questionnaire will be scrutinized.

3.1.1 The co-design approach for the thesis

Regarding FIGURE 9, the pre-design phase is when designers discover and define the problems by monitoring what the users (i.e., the public transport travelers) and other stakeholders respond to using the public commuting system. The dilemmas can be further examined by observations where designers catalog how the users' commuting experience could reveal their behaviors, reasoning paradigms, and possible design possibilities. Subsequently, the defined problems can be transferred to concrete design questions for the following concept generation. The generative phase involves co-design participants (i.e., designers, users, and developers) using a co-design approach to conceive possible handy mobile applications. Once the concrete concept is set, the designer (thesis author) builds the prototype. Then the design proposal is evaluated with users, and concurrently, the final solution is improved in the developmental design phase. Finally, the designer communicates with developers in the post-design phase and provides them with interface proxies and annotations facilitating mobile application implementation. This phase is beyond the extent of the thesis and will be reviewed further in section 5.3.

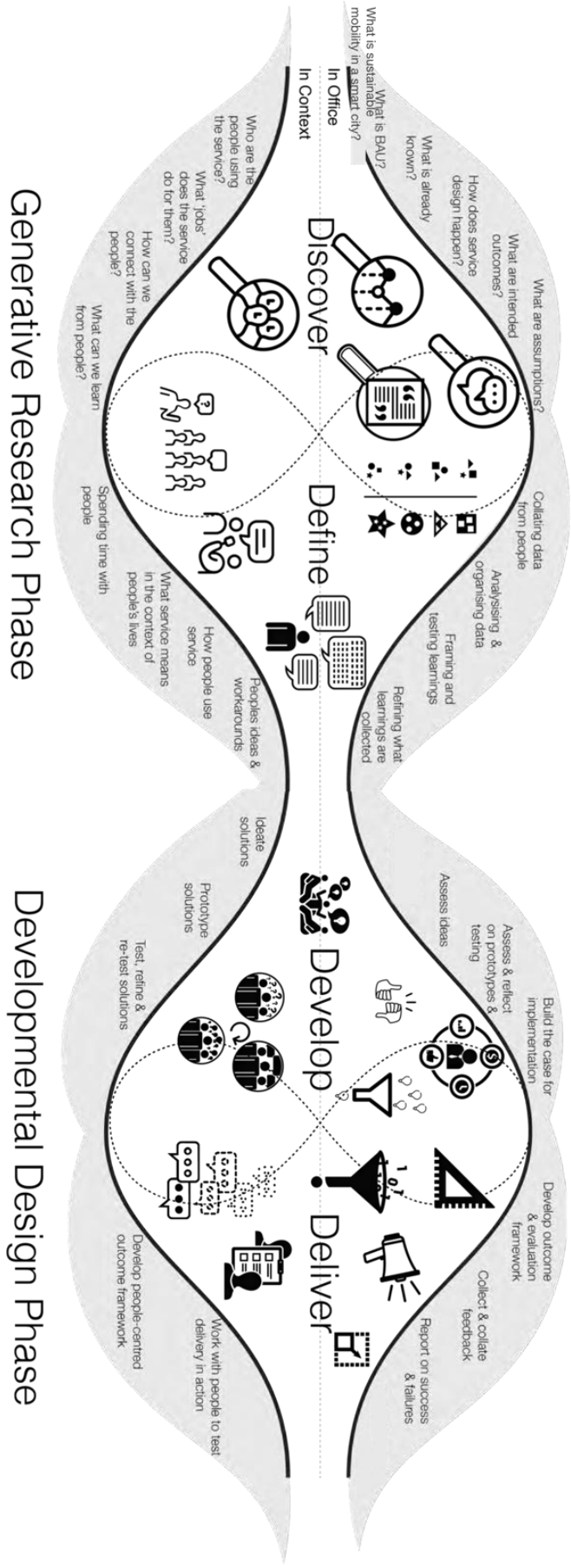

FIGURE 9. The co-design approach in the thesis

3.1.2 The defined user groups in co-design

Due to the coronavirus outbreak, some of the world's most polluted cities have experienced improved air quality due to decreased social and economic activities. Still, as countries worldwide lift their lockdown measures and reopen their economy, the air quality is suspected of becoming polluted once again (FIGURE 10) (Dormido 2020.) Consequently, the goal of the thesis is to resolve this issue in a sustainable and long-term strategy through changing the travel and activity patterns of public transport travelers in a gamified way.

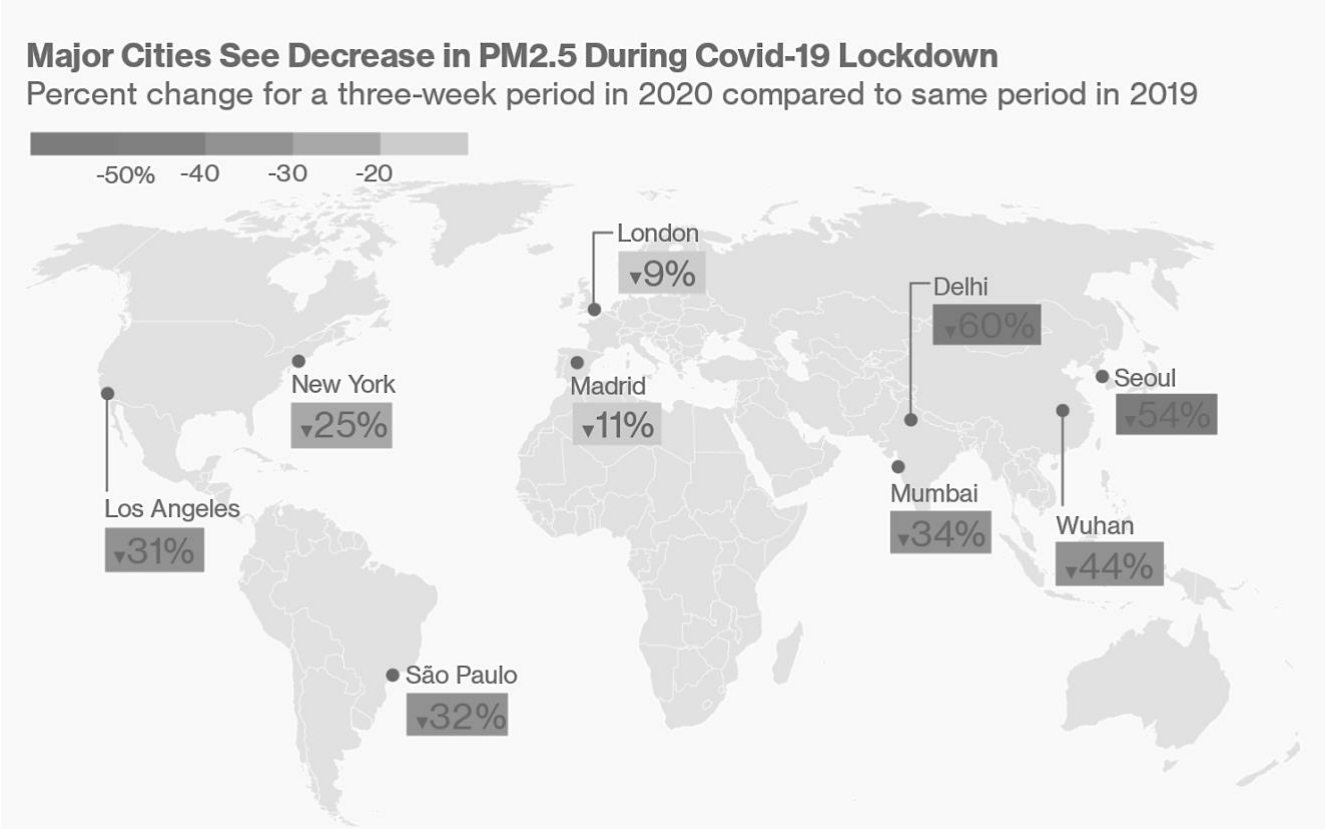

FIGURE 10. Percent change for a three-week period in 2020 compared to same period in 2019 (adapted from Dormido 2020)

Note: Lockdown dates are from Mar. 23-Apr. 13, except for Seoul (Feb. 26- Mar. 18) and Wuhan (Feb. 3- Feb. 24).

Individuals gaining benefits from the product are all external stakeholders, namely smartphone users, commuters who own a private vehicle, care about respiratory health, and environment lovers. They are categorized as the product's end-users, whereas (governmental) public

transport organizations, environmental agencies, and e-commerce sites are comparatively stakeholders and business partners. The author decided to form the business model to deliver to this category of stakeholders.

3.1.3 Questionnaire

The Transition Towns (TT) movement prominently emerges community-based collective climate action initiatives (Hopkins 2008). It aims at assembling community action and raising public empowerment and commitment around climate change, intending to bring about a transition to a low-carbon economy (Bamberg, Rees, and Seebauer 2015, 155-165). An online questionnaire regarding users' perspectives on climate action was conducted with a similar aim, thereby seeking to cultivate climate-friendly behavior in the community through a gamified and sustainable approach. The questionnaire discovered the following principal areas: the mode of transportation that the participants usually commute on; the participant's awareness of the climate change/air quality tracking; participants' expectations and manner towards environmental-related mobile applications.

Additionally, the relevant findings on participants' information were studied to support the research. The online survey was implemented in August 2020. The participants were approached by utilizing social media such as Instagram and Facebook. The invitation link was sent containing comprehensive information about the thesis research, the intention of the questionnaire, and the consent of personal data protection to at most 30 respondents whose origins are from Asia/Southeast Asia (95.6%) and Europe (4.5%). The targeted respondents may vary from the most to the least active public transport users and those based in Western countries. The launch page for the survey is included in APPENDIX 2: Understanding Climate Action Survey. 23 respondents (aged 20 to 39) residing in 4 countries in Southeast Asia, 2 countries in Europe, and 1 country in Oceania took part in the survey. There are 13 females (56.5%) and 10 males (43.5%) in the overall survey. 34 percent of participants had a personal vehicle, and some did not have their vehicles (11.2%). The remaining 54.8% of respondents used to have a personal vehicle such as a car or motorcycle that they usually commute on.

The questionnaire also discovered participants' interest in a mobile application that tracks their carbon footprint for transportation. In terms of climate action awareness, all the participants reported supporting the climate action cause and thought climate action was meaningful.

> *Climate action means stepped-up efforts to reduce greenhouse gas emissions while strengthening resilience and adaptive capacity to climate-induced impacts, including but not limited to climate-related hazards in all countries; integrating climate change measures into national policies, strategies, and planning; and improving education.* (The description part of a question in the questionnaire.)

Accordingly, 73.2% of respondents reflected they were interested in a mobile application that tracks their carbon footprint for transportation, while the remaining (26.8%) appeared to have hesitation in it. While all the respondents claimed that they were aware of the consequences brought about by climate change, 64.3% of them were conscious of their everyday actions. For example, half of them refused to use plastic straws, 23.4% were slightly conscious, and the rest (12.3%) went about their normal daily lifestyle. Donating to or volunteering for any environmental charities and organizations is one of many activities relating to climate action. Most of the respondents (75.5%) found a good and easy way to support climate action, while the others did not agree. Due to the high traffic density, cities usually undergo increased intensities of air pollutants compared to their surroundings (Vos, Maiheu, Vankerkom, and Janssen 2013). TABLE 3 displays the insights about the reasons the respondents would track the air quality of their area.

TABLE 3. The insights about the reasons the respondents would track the air quality of their area (multiple selections applied)

Answer	%
It concerns my health	73.9%
I want to play a part in ensuring healthy air quality	52.2%
I want to know when it is safe to breath outside and when I need to stay home	8.7%
I am living abroad but I want to track the air of my hometown	13%
I usually check the air quality of places I am going to travel	4.3%

The data shows that almost all (86.9%) of the respondents reported that they did or sometimes check the air quality of their area. An environmental-related application on the mobile phone appeared as one of many means the respondents used to read up on climate-related news

and track the local air quality. As noted by Beiler and Kiesler (2018), fake news is not a new problem. However, contemporary researchers are examining fake news with renewed seriousness because the Internet and social media have empowered it to proliferate much more speedily and broadly (Vosoughi et al. 2018; Lutzke et al. 2019). Notably, one issue for which fake news is ubiquitous and potent is climate change (Drummond, Siegrist, and Árvai 2020). Despite the existence of fake news and old data, eight respondents stated they had at least one environmental-related mobile application, and 65.5% claimed that they would/maybe be involved in an application that tracks their carbon footprint for transportation. The survey also explored the respondents' motivations for using environmental-related mobile applications (TABLE 4.). In addition, the responses on the intention of downloading the application(s) were quite comparable to their motivation for using it. Users felt that there was some social impact of using this kind of application.

TABLE 4. The insights about respondents' motivations to use an environmental-related application on mobile phone (multiple selections applied)

Answer	%
The features within the app (heatmap-airflow visualization, carbon footprint scoreboard)	12.3%
Health benefits	92.4%
Incentives/Rewards (travel vouchers, cashbacks, and ecommerce perks)	33.3%
Recommendations from friends and family (trusted and reliable information, user-friendly interface, not too many advertisements)	58.2%

By analyzing the participants' concerns and research studies, the author could confirm that a mobile application is an appropriate alternative to handily support citizens approach a reliable source of information about the airflow and their exposure of carbon footprint for more sustainable transportation in smart cities. The professional development team will guarantee the reliability and trustworthiness of the database and security for the end-users. Throughout the application, users can advance climate action and obtain benefits in an active and timely way trustworthily. In addition, the participants expect the application to have specific features, such as a carbon footprint scoreboard, airflow/health benefit visualization, rewards, virtual community, and attractive incentives.

3.2 Develop

In Develop phase, the author would introduce the customer empathy map, site map, user interface and interaction design.

3.2.1 Customer Empathy Map

The empathy map method (EMM) is a creative practice that can be implemented in design thinking throughout design thinking phases 'Understand' and 'Perception' (Beims 2021) for integrating observations from all team members, classification of customer demands, and attaining further customer insights (Brown 2008, 84-92; Ingle 2013). The empathy map method drives the team towards a logical aspect of observations, customer requirements, and insights. The classified customer needs and insights are fundamental for progressing innovative concepts (Bittner and Shoury 2019, 228.) Three to four participants are suggested for fruitful empathy map method sessions; however, the author individually took care of this work due to the lack of personnel. FIGURE 11 presents the six topics discussed throughout the empathy map method and their procedural order (numbers one to six) (Ferreira et al., 2016).

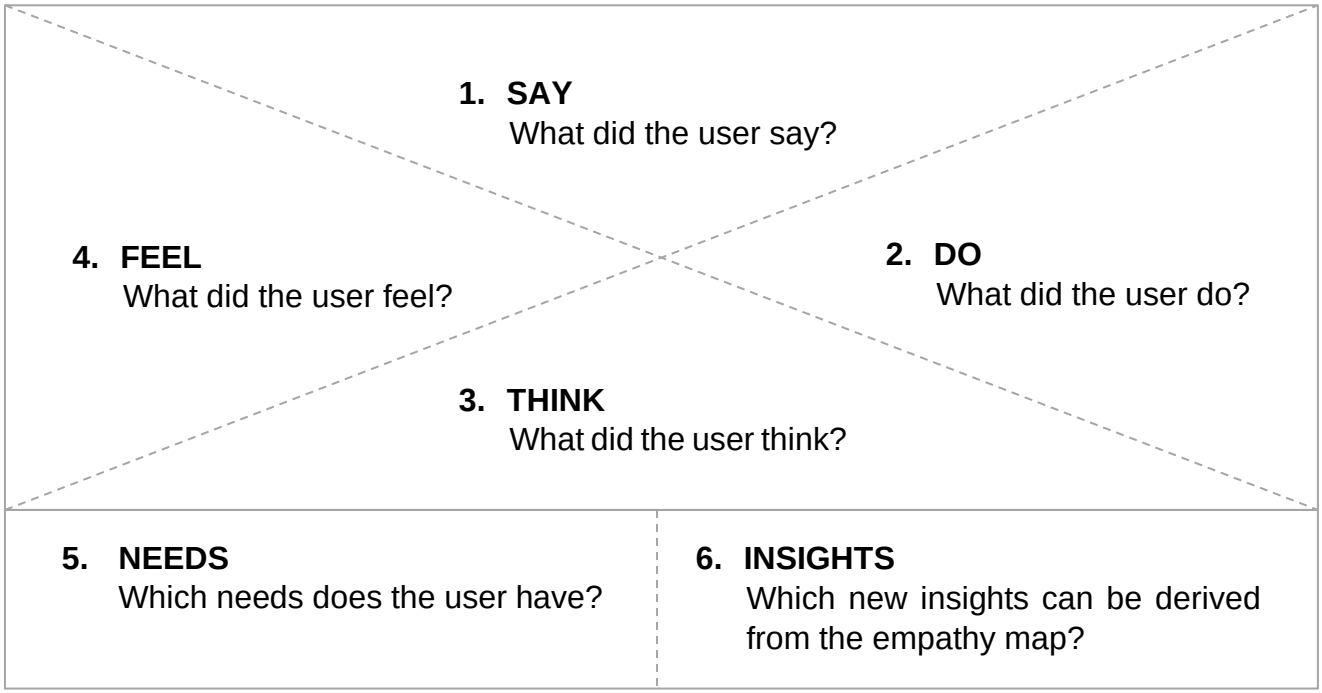

FIGURE 11. Empathy map method

At first, a literature review was conducted to derive the initial requirements of the mobile application for sustainable mobility in a smart city. The online collaborative whiteboard platform was searched for explaining complex processes and systems with visual mapping and diagramming. The identified requirements are shown in TABLE 5.

TABLE 5. Mobile application for sustainable mobility in smart city conceptualizations

Key objectives	Specification of requirements	Types
Predict airflow particles direction	If the application can predict airflow and if a hazardous area falls into the path of the airflow, the application can alert the people falling on the path of the airflow	Integrated airflow map
Incentivize users to lower carbon footprint through a reward-based system	The application must reward the users for helping them stay motivated to lower their daily carbon emission level to as minimum as possible	User carbon footprint scoreboard
Using Dynamic Rewards to motivate users to take public transport on pollution-heavy days	When the application gets a pollution alert, it must aim to increase the motivation of the users to keep individual level carbon emissions at the lowest possible value	Air pollution alert feature, open application programming interface

Based on them, the author could learn from the insights which provide information about what a customer needs to fulfill their desires and needs. The application's conceptual knowledge base was derived and represented via the EMM to reflect the creative, usually visual approach - and promising, as the thesis's application concept could benefit from it (FIGURE 12).

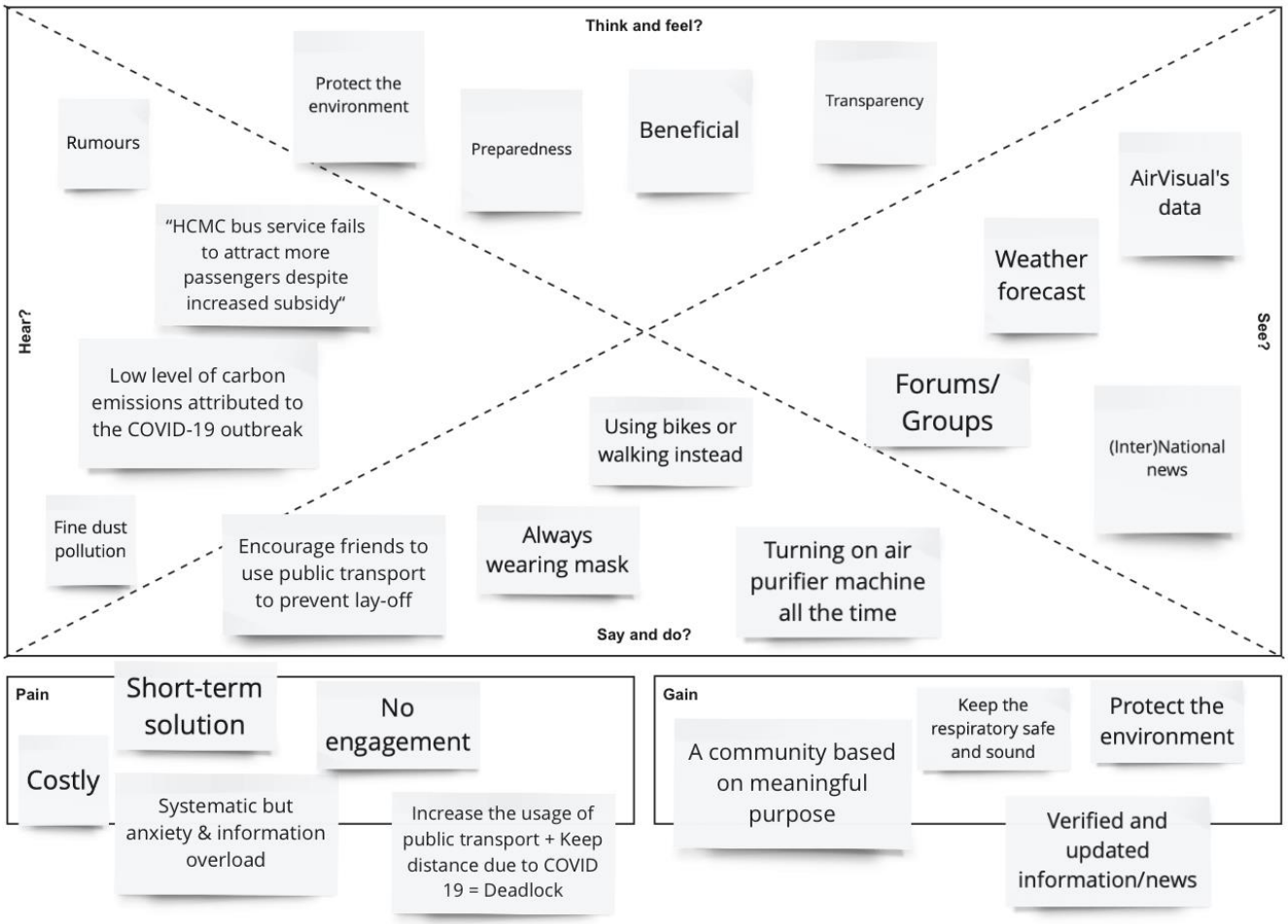

FIGURE 12. Customer empathy map (designed on Miro.com)

As proof of concept, a solution conceptualization has been developed, which instantiates the interaction between the application and other users. Using the solution conceptualization, the author could apply a technique to define the customer experience and improve the application's experience, which is mapping out the customer journey. Richardson (2010) stated that a customer journey map is simply a diagram that illustrates "the steps the customer(s) go through in engaging with the company, whether it be a product, an online experience, retail experience, or a service, or any combination" (Richardson 2010, 2-5). FIGURE 13 scripts all possible emotional factors, out-of-box experience, thereby guiding the customer through the first steps of using the application and minimizes the question or confusion on the way. Accordingly, a sample user, Chau, was created based on a persona of a university student to demonstrate a user's experiences and emotions when using the application step by step. Chau is a Vietnamese student who is starting her journey on taking climate action by using public transport sustainably. As a freshman at university in a big city, she must plan how to travel in a budget, conveniently, and in a ecological way in a very new place that she has not ever been

to before. However, she has experience in traveling by coach from her hometown to the city. As a result, it takes Chau not too long to learn what actions are expected to perform her tasks using an application to commute within the city. Chau finds it easy to look for modern applications that can make her life more convenient and efficient with her high-tech generation and broad relationships. Chau carefully manages her spending, and cash-free or contactless payments are a new purchase routine in Vietnam. According to Chau, every action can support climate action if the user sincerely concerns their health and future.

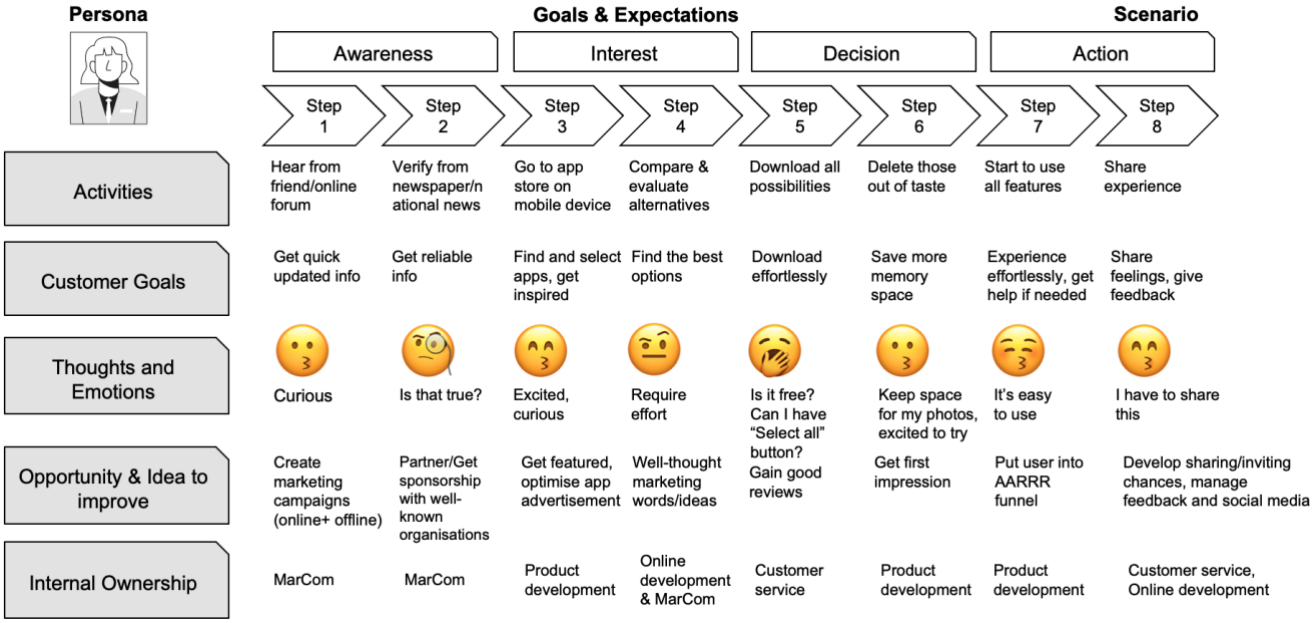

FIGURE 13. Customer journey map

3.2.2 Sitemap

After mapping and defining opportunities by employing the customer journey map, the research scope can be narrowed and focused on design. In essence, the assumptions based on the review of literature are validated by questionnaire. The idea of introducing a mobile application as a solution looks promising but requires further research into the technology to bring it to real life and to find a future-proof solution. Accordingly, the research moves to the next step, crafting the solution to the identified issues. Main screens of the application and their primary content with a sitemap are listed and linked. This work helps with aligning each screen to the design objectives they serve (FIGURE 14). The semantic of sitemap initially and often refer to the website. Bernard (1999) claimed that sitemaps might benefit users in conceptualizing the

framework of a website and equip them to become more efficient in gaining information. Consequently, it is relevant to use a sitemap in designing an application for organizational purposes.

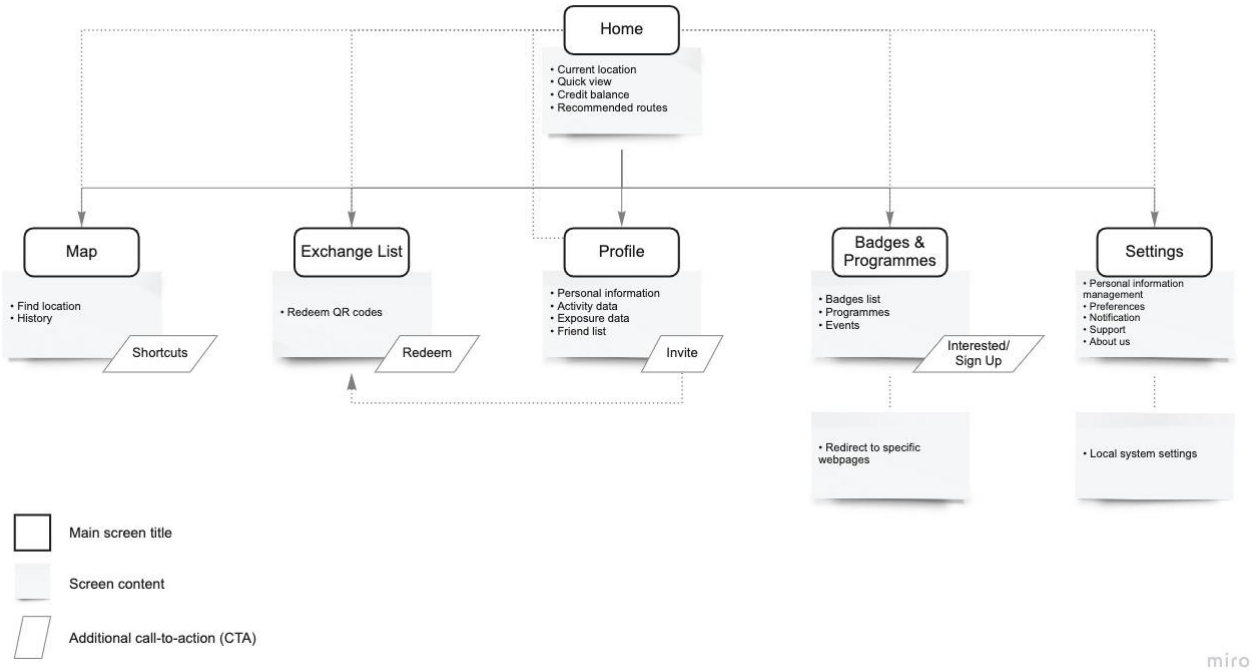

FIGURE 14. Sitemap

3.2.3 User Interface & Interaction Design

Following the determined sitemap and the user flow (FIGURE 15), through wireframes and mockups, the author visually detailed the user interface, including layouts, color schemes, iconography, visual style, and interaction patterns.

A wireframe is a low-fidelity design for illustrating structure, content, and functionality on a product (i.e., application, page). To be specific, it is a layout of a product, which demonstrates what interface elements exist. Before the visual design and content are attached, it is highly advantageous in the early progress to build the fundamental structure of the interface. (Experience UX 2018.) Similarly, a wireframe helps to implement a visual perception of a product and the logic of interaction (e.g., navigation). As against wireframes depicting a product's structure, a mockup explains the appearance of the interface. A mockup supports

addressing resolutions on a user interface's color schemes, visual style, typography, and iconography.

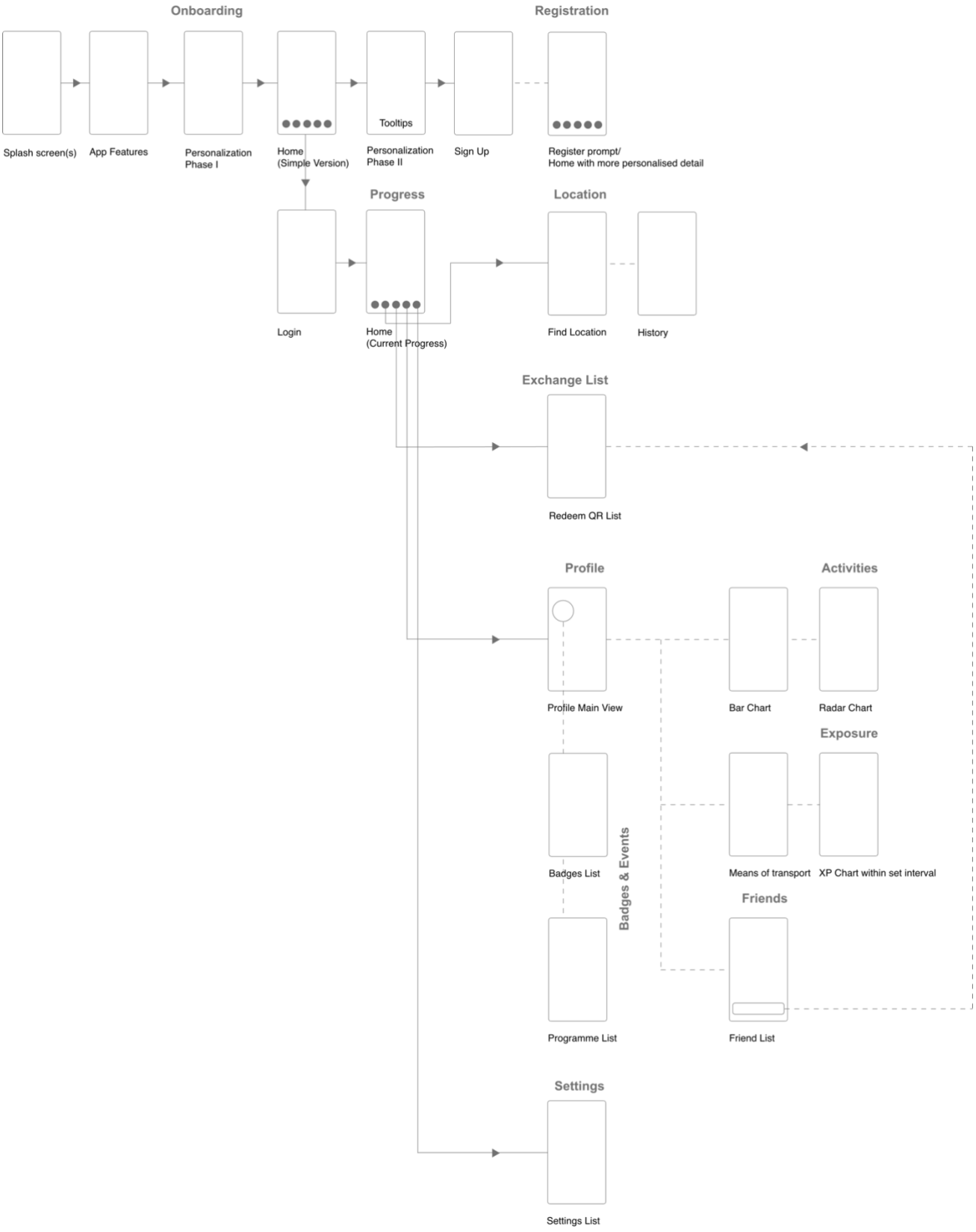

FIGURE 15. The application flow overview

Based on the application flow overview, it is clear to understand that there are two distinct flows for new users and users: guests and registered users. This implementation helps the application approach end-users more comfortably and allows users to opt-in the main features eventually. One of this application's goals is to hack the user growth by utilizing the AARRR framework (Balke 2017). In detail, the framework consists of the five most important metrics, e.g., for a startup, to focus on: Acquisition (Where the user/customer come from); Activation (How the user/customer feel in the first experience); Retention (The number of users/customers the product is retaining and why losing the others); Referral (How the users/customers turn into advocates); Revenue (How revenue can increase).

Once the user downloads the application, they have two options: continue with the guest plan or registration plan. The application greets the user with onboarding screens in which shows their main features, basic options for personalization and asking for their willingness to sign up. To be specific, on opening the application for the first time, it asks for user location, age, and gender-related information. Then, the user gets a notification regarding their present location only. Users who have installed the application can get pollution alert notifications without registering. As a means of engaging and fulfilling the activation metric, the application demonstrates a set of fundamental and necessary features and provides users with real-time data about air quality and suggestive routes.

The application employs tooltips and in-app notification to enable users to look for location, join the sustainable mobility usage marathon, and hunt for redeeming code according to their efforts in low-carbon traveling. This employment strives for their increase in logging in, meaning to put them in the next stage of the tunnel – retention. More than that, the Octalysis shows that users will feel ownership, accomplishment, and epic meaning. In Home and Exchange List screens, the application has an extensive list of appliances and vehicles with CO2 emission levels by which the user can know the amount of emission caused by themselves in a day. If the value is under a specific threshold value, they are rewarded a certain number of points. This feature motivates end-users to use more public transport and appliances more efficiently. Moreover, points can be redeemed as online shopping coupons and cashback, public transport passes, and store discounts.

When users move toward the Profile screen, they get a full view of all data and metrics of their activities, exposures, friend list, badges, and more. If the user gets an alert for air pollution, the reward point amount also increases. However, it can only be redeemed after the application verifies that the user has reduced their carbon emission levels. The application determines a reduction of at least 10 percent from the original carbon emission levels. Consequently, these features make the application more interesting by giving users social influence and relatedness, accomplishment, and unpredictability, and curiosity. The idea behind crediting a user's account on pollution alert days is that if the user can see the benefits they could redeem, just a touch away, they would be more incentivized to adopt more eco-friendly practices to redeem them. It again fulfills the ownership and possession core drive of gamification. In an epic way, users help the environment by lowering particulate matter in the air at an individual level and being more resilient against the upcoming air pollution in their country of residence.

Most actions in the application are to read data and tap to see more or show the code to the code reader. Hence, the flow of interaction is designed quite simply with vertical and horizontal swipe movements. The sizes of elements are intentionally adjusted evidently, and the brightness adjustment of the phone is automatically higher when users would like to scan the code. Above all, application interactions should be as minimal as possible so that users do not need to use both of their hands in their traveling context.

Given that the application must be compatible with various mobile phone operating systems, the design is conceptualized in an iOS phone. The home screen reflects whether the user is new to the application or the returning user. The application should show some primary and general data according to the personalized information obtained from the personalization phase for new users and those who opt-out of signing up. Thus, it enables the user to grasp how the application works and can serve their basic needs, i.e., checking particulate matter (PM) pollution, air quality index (AQI) (FIGURE 16, left). Based on the personalization phase II, the full version for those already signed up comprises Credit Balance and Recommended Routes features beside Quick View (FIGURE 16, right).

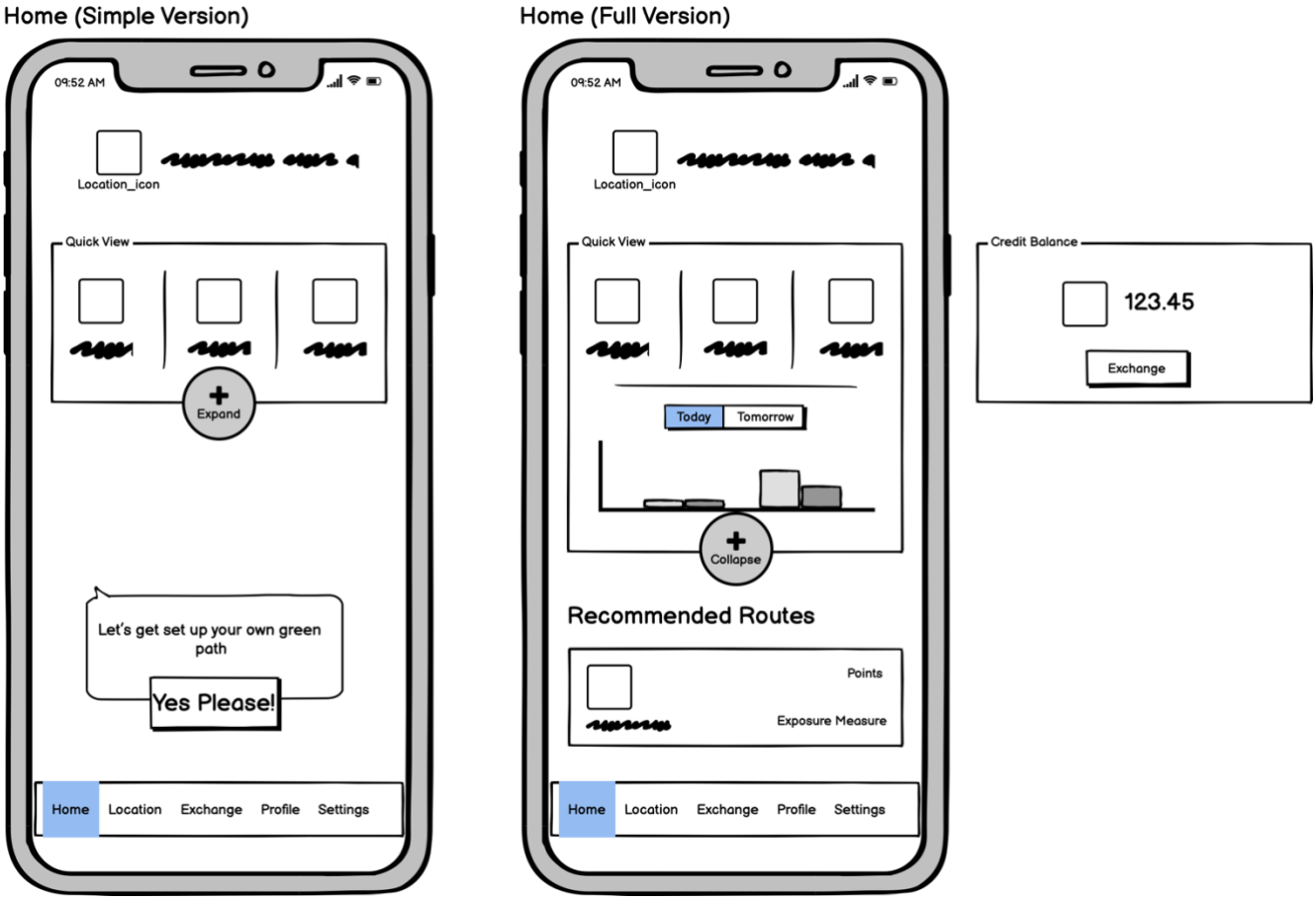

FIGURE 16. The wireframe of the user interface: Home screen – Simple version (left), Full version (right)

The bottom sticky menu bar is the central navigator within the application. Hence, it is visible on every screen, and one bolder icon works as the screen indicator. The user interface design patterns of Location and Exchange List screens are applied with similar-looking user interfaces, to which functioning users have become explicitly accustomed. It will help with task achievement, efficiency, and satisfaction from users. Using the interface as a button bar to navigate between Find Location and History, users can promptly search for a lesser amount of produced carbon dioxide route by specific means of transport and track their history of mobility (FIGURE 17, top). As such, the customized map with detailed data and imagery for display on mobile devices can be featured by using the Maps JavaScript application programming interface (API) (Google 2021). However, the thesis will not cover this area. Exchange List includes the list of redeem codes, in which the codes are in QR form or a sequence of characters according to the collaborators' requirements and the code readers on, for example, buses, trams, or metros (FIGURE 17, bottom).

FIGURE 17. The wireframe of the user interface: Location screens (top), Exchange List screens (bottom)

Profile screen seems like the heart of the application because all tracking data, visualized as various kinds of the chart, and the PBLs are also briefly shown and accessed fully from here. Users are encouraged to invite more friends to spread the word, and together they can lower

the carbon footprint in the city. A default redeem code is available whenever users try to invite a friend for the first time. (FIGURE 18.)

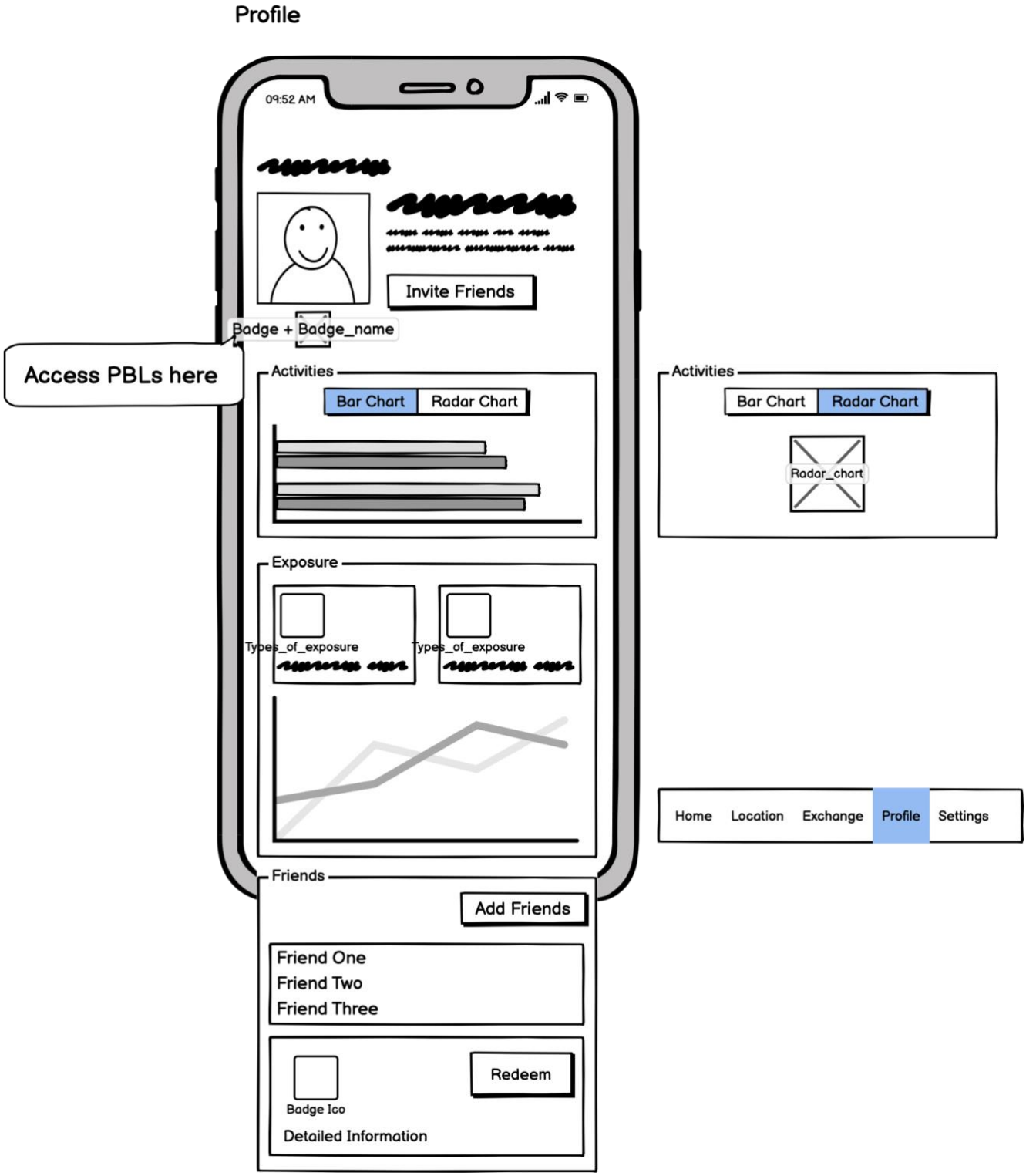

FIGURE 18. The wireframe of the user interface: Profile screen

The author expected to keep the interface simple to minimize the cognitive load. The term cognitive load indicates the amount of reasoning processing power a user needs to use a product (Hannah 2019). The author would withdraw undesirable elements and be evident in the language used on labels and messaging to keep the cognitive load to a least. Also, be strategical in using color and texture to direct or redirect the user's attention toward or away from items. In line with Material Design's principles (Google 2014), the color scheme follows three principles: hierarchical, legible, and expressive. Additionally, when applying color to UI, this web page depicts consistent, distinct, and intentional principles.

In accordance with the color principles, the selected color indicates the interactivity, relatedness, and level of prominence of an interface component, i.e., significant elements should stand out the most. Also, texts and critical elements, e.g., icons and charts, should satisfy readability standards displayed on the colored backgrounds across all screens. The consistency of UI elements allows users to feel more comfortable and master new aspects more promptly. Consistency makes the interface design identifiable and predictable. Ultimately, specific colors are utilized consistently in the application, thereby always implying the same thing, regardless the context. Then, the users can transfer that skill to other parts of the application.

The color palette consists of purple, red, green, yellow, and grey (FIGURE 19). Purple is the primary color, whereas yellow is the secondary color. In the home interface, the primary (purple) and the secondary color (yellow) are selected to represent the theme of the product. To be specific, purple (namely Electric Violet), yellow (namely My Sin), and green (namely Apple) are utilized according to the triadic combination on the system prompts. However, to create a contrast and slight gradient between them, the primary and secondary variants are chosen for the system prompts while the white and black are used on the additional UI colors, i.e., surfaces, typography, and iconography.

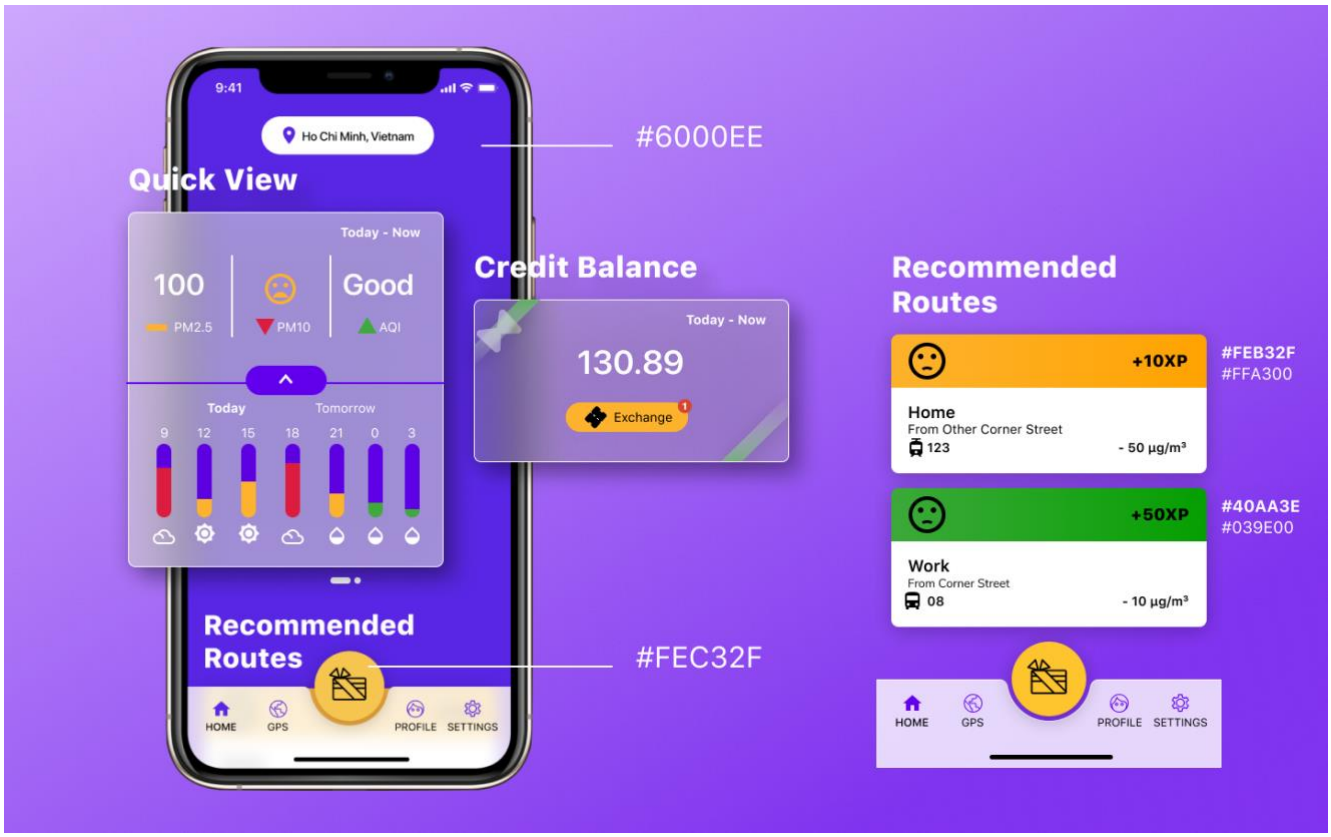

FIGURE 19. The color palette of the application interface

The air quality information is depicted more distinctly for the user than other elements, but still familiarly with users. Therefore, these colors are always combined with their triadic groups, white or off-white, which draws more attention. In regard to the yellow, it is used for buttons and interactive areas. To enable the text to appear clearly and legibly, the text on the purple surfaces will be in white, and the black text fits the yellow buttons and the white surfaces. FIGURE 20 shows the accessibility examination on the primary and secondary colors together with their variants.

To upgrade the application interface according to the latest design trend, the author employed glassmorphism in the design. Its preceding sibling – neumorphism, did not completely take over the design picture unless this style is used scarcely and the objects on backgrounds hold their structure and readability without the decoration. One of the glassmorphism defining characteristics that slightly affect color scheme selection is the vivid color background highlighting the blurred transparency. The other three characteristics of glassmorphism include: frosted glass using a background blur (as known as transparency); a multi-layered approach with objects floating in space; a detailed, thin border on the translucent objects.

The origin of background blur was in 2013 with iOS 7, then The Acrylic element of Microsoft's Fluent design system also showcased this effect as an integral part of the system. Following Material Design principles, together with Neumorphism, this style is not that accessible. Hence, its application in the product is constrained to be the background for big cards and bottom navigators. As such, it purely works as a decoration, not an integral part of the experience. (Malewicz 2020.)

FIGURE 20. Accessibility checks according to the Color Tool from Material.io

Icons help classify actions and provide information. The author considered understandability and clarity when designing the icon. Concerning illustrating the air quality, smiley icons combining with charts, i.e., column chart, line chart, and hexagon chart, were utilized to visualize informative notifications/messages about carbon footprint towards a specific route or area. The author leveraged a color gradient from red (strongly alert) to green (strongly recommend) to reflect air quality. Besides, the application uses the weather icon pack to illustrate the real-time weather status and a set of icons for navigation purposes, and some basic geometry shapes to visualize the fluctuation of the air quality.

The last step of Develop phase is prototype solutions. The prototype and the idea were first introduced at JunctionX Asia in June 2020 yet launched publicly on any digital distribution services such as Apps Store and Google Play. The author prototyped the defined concept via

Figma and Adobe XD platforms. These tools were used to test interaction quality and accessibility. The prototype, as well as the minimum viable product (MVP), played an important role at that time to help the audiences (as known as future customers/users) grasped a fundamental idea of the application and how it can be considered as an add-on factor in the cutting down carbon footprint journey.

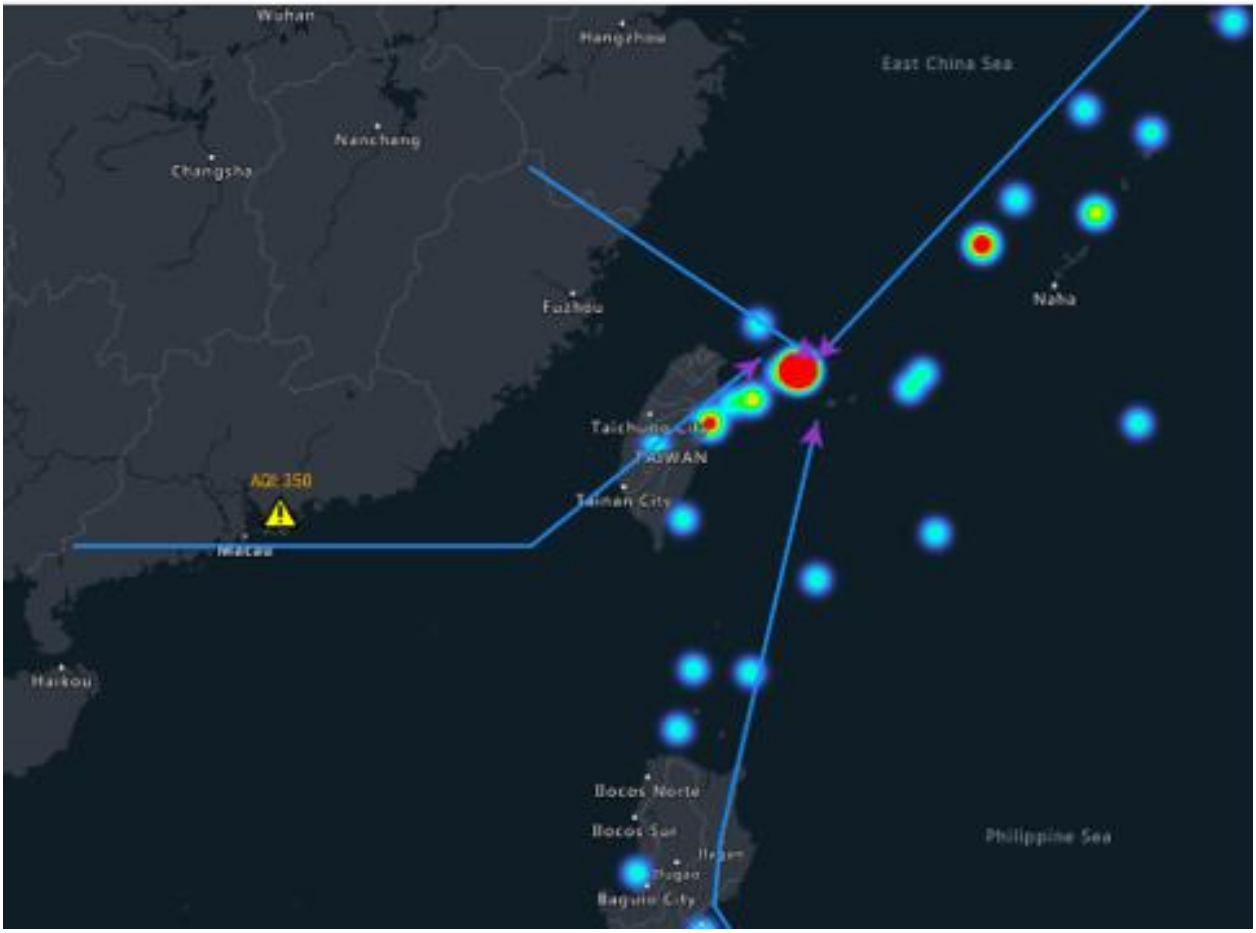

FIGURE 21. Data shown is for visualization only, does not represent present values

In the CarbonScape project submitted to JunctionX Asia, the prototype was clickable with a flair of animation to make it more genuine and interactive. The team developer built the MVP's heatmap by Azure Maps to give users an idea of where a possible airflow may happen (FIGURE 21). The arrows represent the airflow direction from colder places to hotter places, as airflow tends to happen from colder to hotter regions. The alert symbol shown near Hong Kong represents unqualified air quality, and there is a high chance that the flowing air will carry pollutants along with it from Hong Kong towards Taiwan. It alerts the people in Taiwan that polluted air might be coming their way to be prepared by taking precautionary measures. Additionally, TABLE 6 shows technologies that the developer used to deliver the MVP.

TABLE 6. Technologies used in CarbonScape project

Name	Purpose
Azure Maps	To plot the heatmap and airflow
Azure Functions	To get data as JSON API written in Python
Azure Container Registry	To host the Docker container running web application
Azure Web App	To access the web application running in Azure container
React JS	To render the web and application frontend
Python	To handle data and build an API
Figma	For rapid prototyping

In the scale of this thesis, the author intended to renovate the user interface and interaction of the application (FIGURE 22) based on the comments of the old concept, thereby new features and elements not yet delivering to users to collect and collate feedback and be evaluated by stakeholders.

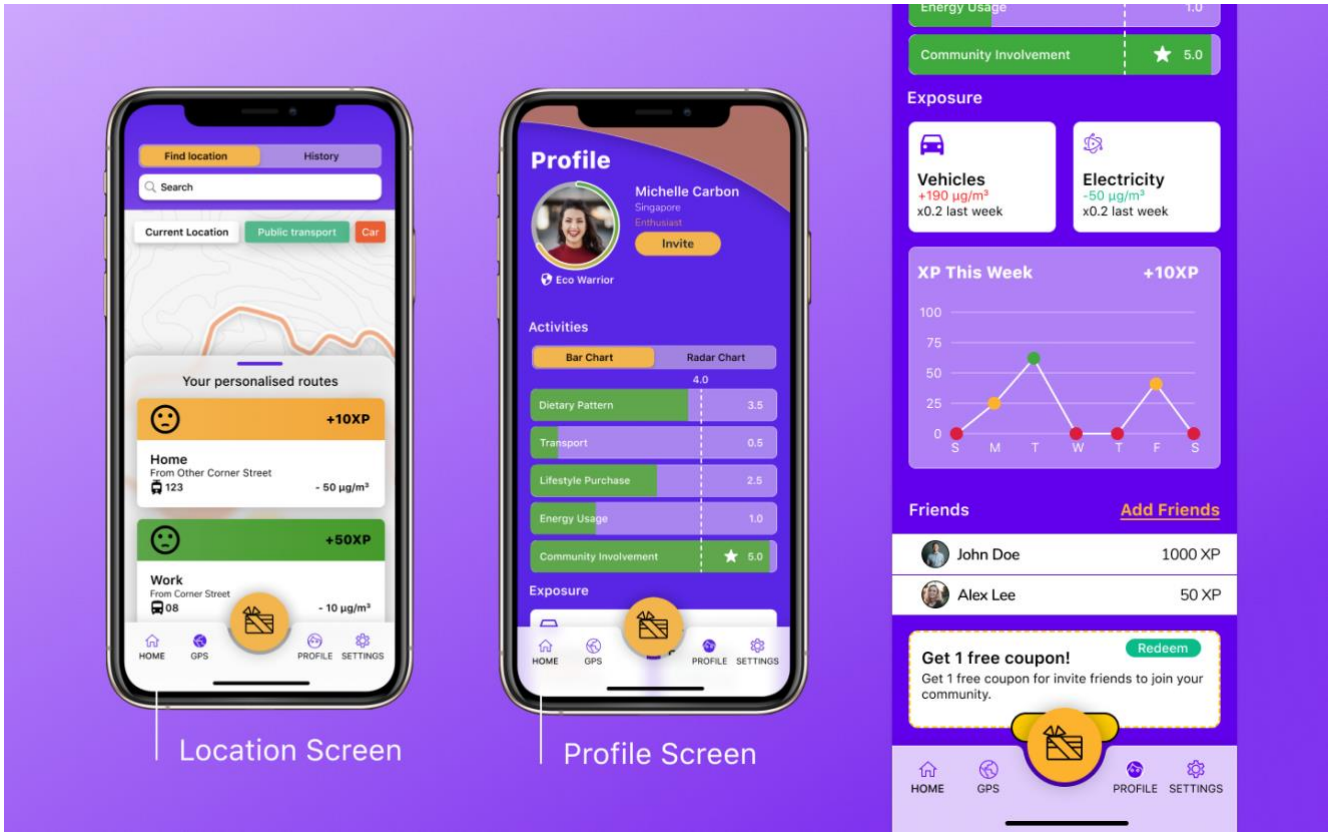

FIGURE 22. Interfaces of Location and Profile screens (adapted from the author's Figma file)

3.3 Deliver

To explicitly describe the design specifications of the application, Figma provides the feature called Inspect for developer handoff (FIGURE 23). Designers can invite developers into Figma to inspect files, take code snippets, or export assets (Figma n.d.). Figma frames can be efficiently exported to Zeplin for tailored specifications, assets, and code snippets to share with developers.

Above all, one of the cores of the thesis is to deliver seamless experiences to users. Hence, this dynamic procedure cannot be promptly presented through motionless pictures. Therefore, a demo video or a flash animation about interacting with the application, i.e., how the state of interactive components varieties, should be addressed to help developers understand the behaviors.

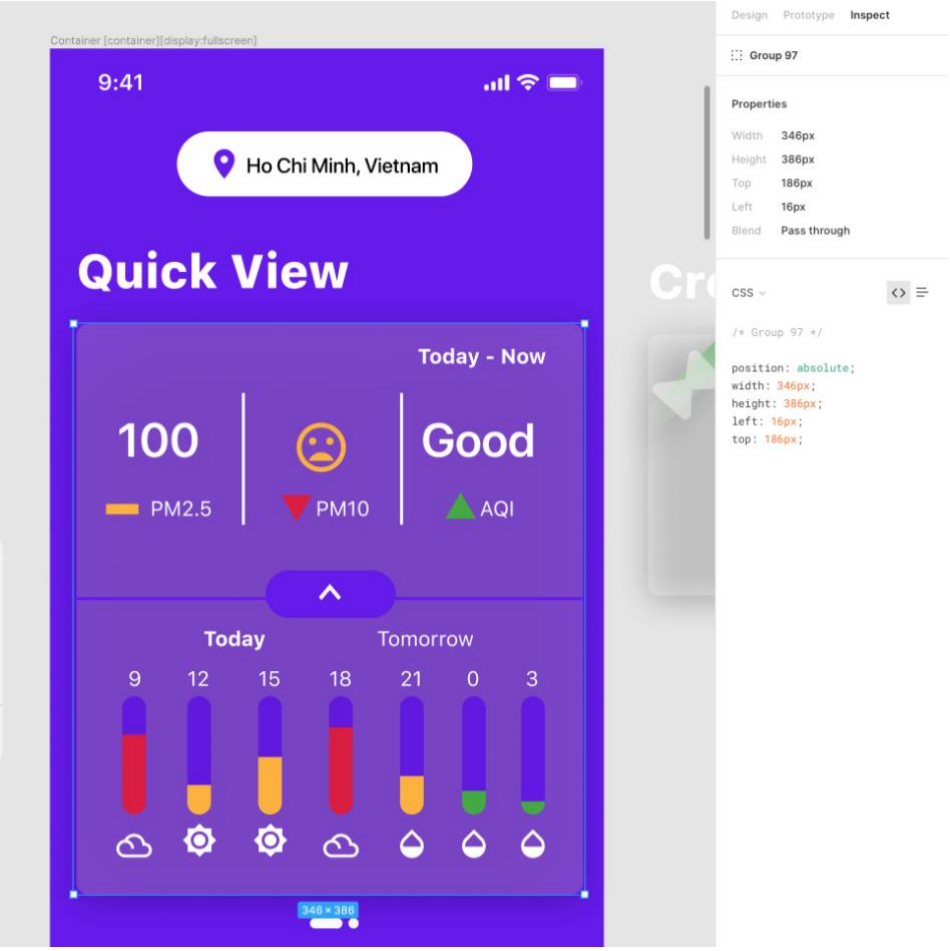

FIGURE 23. Screenshot shows how the Inspect feature works (adapted from the author's Figma file)

Evaluation is a crucial stage for not only the Deliver phase but also the whole design process. The role of evaluation is to assess designs and test systems to ensure that they behave as the designer expects and meet user requirements. It is not a single phase in the design. Evaluation techniques can be considered under two general headings: expert analysis and user participation (FIGURE 24).

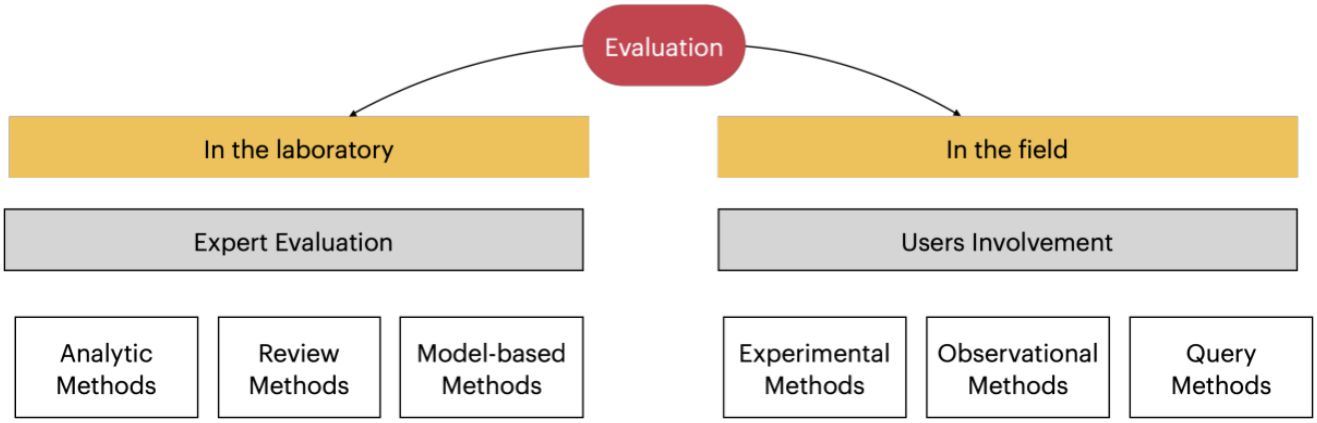

FIGURE 24. Evaluation approaches

Cooperative evaluation seems to be the most suitable method to parallel the co-design approach in the future. Cooperative evaluation is an alternative to the think-aloud evaluation technique, in which the user is encouraged to perceive himself as a collaborator in the evaluation rather than just a subject. Not only getting users to think aloud, but the evaluator can also ask such questions as "why" and "what if." Besides, the user can ask the evaluator for an explanation if problems arise.

4 DISCUSSION AND CONCLUSION

During the research through design process to complete this thesis, the author managed to renovate a concept, which was also the author's work, and be in the effort to deliver a smoother flow of interactions. The new application concept is believed to leverage on a gamified approach to change activity habits of personal vehicles owners and the majority of travelers in a smart city into a more environmentally friendly way. On the solid base of CarbonScape's project, the author would like to continue the vision to be advocates of determined climate action, a plot in reducing carbon emissions level in a smart city, or to-be smart city thereby opening their economy.

4.1 Gamified applications in practice

Among the current applications in online markets, gamification does not seem that much unfamiliar to people when it was first introduced. However, it does not mean that it is easy to gamify a product, especially a mobile application, in this thesis context. From a personal view, the process requires much more time for the author to genuinely understand the concept, conduct enough questionnaires and evaluations in the field, and look for a suitable market to launch the idea. Since the application has yet been introduced, pain points and flows are merely the author's assumptions and hypotheses. It properly affects the completeness of the product. However, the thesis's application is undoubtedly a promising and approving idea and concept. To be specific, the older version of this idea was in the top 3 of developing for the social good challenge by Microsoft, and climate change, and the smart city challenge by the National Council on Climate and Air Quality.

4.2 Limitation and future research

As mentioned before, the most significant limitation of the thesis is that it lacks time and evaluations. Secondly, a polished application is always a better demonstration than a prototype. Hence, future research on programming and technologies is required to fill the gap between ideas and the practical product. The author started her gamification design journey to showcase that her knowledge and resources in the thesis are insufficient compared to an

expert in the relating field. The major limitation of this thesis is that it is pretty general and does not focus on a specific country or area. Therefore, it is hard to generate a business plan to enter the market, which affects the Exchange List screen's feature. The author hoped this application can connect to the green community and businesses focusing on sustainable products. The scale of the thesis's topic does not cover all factors that can reduce waste, e.g., food waste, energy waster, and more, thoroughly. Finally, the user involvement in the thesis is not sufficient, especially during the Develop and Deliver phases. The developer participated in the incubation stage (the previous version of the concept), but it is not enough to make the idea come true.

Regarding potential growth areas, gamification of the application incorporates features, such as connecting with Facebook friends and having a point scoreboard to encourage some friendly competitive spirit. Another aspect would be trying to include AR-based games, in which the user gains knowledge on the carbon emissions emitted by a particular appliance by virtually clicking on it.

4.3 Implications

This thesis presents an experimental case of co-design practice in the context of sustainable mobility in a smart city, which contributes to a body of research from various viewpoints consolidating co-design, user interface design, user experience design, and gamification design. More specifically, the thesis introduces a co-design process in application development, in which users, designers, developers, and stakeholders can build strong engagement and shared perception to assure the success of product development.

4.4 Conclusion

The research investigated how a co-design approach can contribute to designing a mobile application that supports climate action in cities within the context of sustainable mobility. In-depth document studies and questionnaires were conducted to understand user experience, needs, and expectations to fulfill this goal. The resulting design concept will be evaluated by the users soon. After reflecting on the whole co-design process, the author concluded that the co-design approach is beneficial for defining social problems, developing concepts laying a foundation for the final solution, and refining the solution efficiently. However, the research

does not have the involvement of developers may lead to the inconsistency between the final product and the proposed design concept. Therefore, future researchers should consider investigating the impact of collaboration and communication among users, designers, and developers throughout the whole design process of software development.

REFERENCE

Alben, L., 1996. Quality of Experience: Defining the Criteria for Effective Interaction Design. *Interactions,* 3(3), pp. 11-15.

Anon., 2018. *What is wireframing.* [Online] Available at: https://www.experienceux.co.uk/faqs/what-is-wireframing/ [Accessed 5 May 2021].

Balke, M., 2017. *AARRR Framework- Metrics That Let Your StartUp Sound Like A Pirate Ship.* [Online] Available at: https://medium.com/@ms.mbalke/aarrr-framework-metrics-that-let-your-startup-sound-like-a-pirate-ship-e91d4082994b [Accessed 12 May 2021].

Bamberg , S., Rees, J. & Seebauer, S., 2015. Collective climate action: Determinants of participation intention in community-based pro-environmental initiatives. *Journal of Environmental Psychology,* Volume 43, pp. 155-165.

Banister, D., 2008. The sustainable mobility paradigm. *Transport Policy,* 15(2), pp. 73-80.

Beiler, M. & Kiesler, J., 2018. 'Lügenpresse! Lying press!' Is the press lying?. *Trust in Media and Journalism: Empirical Perspectives on Ethics, Norms, Impacts and Populism in Europe,* p. 155–79.

Beims, M., 2021. *Design Thinking im IT-Service-Management.* [Online] Available at: http://www.cio.de/a/design-thinking-im-it-service-management,3260384 [Accessed 29 April 2021].

Benevolo, C., Dameri, R. P. & D'auria, B., 2016. Smart mobility in smart city. In: *Empowering organizations.* s.l.:Springer, pp. 13-28.

Bernard, M., 1999. Sitemap Design: Alphabetical or Categorical?. *Usability News,* 1(2).

Bevan, N., 2009. *Classifying and Selecting UX and Usability Measures.* New York, Association for Computing Machinery.

Blohm, I. & Leimester, J. M., 2013. Gamification. *Business & information systems engineering,* 5(4), pp. 275-278.

Brown, T., 2008. *Design Thinking.* s.l.:Harvard Business Review.

Bucciarelli, L., 1994. *Designing Engineers.* Cambridge, MA: MIT Press.

Burkett, I., 2012. An introduction to co-design. *Knode: Sydney, Australia,* p. 12.

Burkett, I., 2012. Co-design for Social Good: The Role of Citizens in Designing and Delivering Social Services, Part One. *An introduction to co-design.*

Chesbrough, H. W., 2003. *Open Innovation: The New Imperative for Creating and Profiting from New Technology.* Boston: Havard Business School Press.

Chesbrough, H. W., Vanhaverbeke, W. & West, J., 2006. *Open Innovation: Researching a New Paradigm.* Oxford: Oxford University Press.

Chou, Y.-K., 2015. *Actionable Gamification: Beyond Points, Badges, and Leaderboards.* s.l.:CreateSpace Independent Publishing Platform.

Cross, N., 2006. *Designerly Ways of Knowing.* London: Springer-Verlag.

Dameri, R. P., 2014. Comparing Smart and Digital City: Initiatives and Strategies in Amsterdam and Genoa. Are they Digital and/or Smart? Progress. *IS,* pp. 45-88.

Deterding, S., Dixon, D., Khaled, R. & Nacke, L., 2011. *From game design elements to gamefulness: defining gamification.* Tampere, Proc 15th MindTrek conference, pp. 9-15.

Dodero, G., Gennari, R., Melonio, A. & Torello, S., 2014. *Gamified co-design with cooperative learning.* [Online] Available at: https://dl.acm.org/citation.cfm?id=2578870 [Accessed 20 March 2021].

Dormido, H., 2020. *These Cities Now Have Less Air Pollution During Virus Lockdowns.* [Online] Available at: https://www.bloomberg.com/graphics/2020-pollution-during-covid-19-lockdown/ [Accessed 20 April 2021].

Drummond, C., Siegrist, M. & Árvai, J., 2020. Limited effects of exposure to fake news about climate change. *Environmental Research Communications,* 2(8), p. 081003.

Edvardsson, Bo; Gustafsson, Anders; Kristensson, Per; Magnusson, Peter; Matthing, Jonas, 2006. *Involving Customers in New Service Development.* London: Imperial College Press.

Elflein, J., 2021. *New cases of COVID-19 worldwide from January 23, 2020 to May 11, 2021, by day.* [Online] Available at: https://www.statista.com/statistics/1103046/new-coronavirus-covid19-cases-number-worldwide-by-day/ [Accessed 12 May 2021].

Ferreira, B. M., Barbosa, S. D. J. & Conte, T., 2016. *PATHY: Using Empathy with Personas to Design Applications that Meet the Users' Needs.* Toronto, ON, Canada, HCI International.

Figma, n.d. *Create a seamless design workflow.* [Online] Available at: https://www.figma.com/product-integrations/ [Accessed 12 May 2021].

Gartner, 2012. *Gamification: engagement strategies for business and IT,* s.l.: Report G00245563.

Giffinger, R. et al., 2007. Smart Cities: Ranking of European Medium-Sized Cities. *Centre of Regional Science (SRF).*

Google, 2014. *The color system.* [Online] Available at: https://material.io/design/color/the-color-system.html#usage [Accessed 8 May 2021].

Google, 2021. *Maps JavaScript API.* [Online] Available at: https://developers.google.com/maps/documentation/javascript/overview [Accessed May 2021].

Hall, P., 2000. Creative cities and economic development. *Urban Studies,* Volume 37, pp. 633-649.

Hannah, J., 2019. *What Is A User Interface, And What Are The Elements That Comprise one?.* [Online] Available at: https://careerfoundry.com/en/blog/ui-design/what-is-a-user-interface/ [Accessed 6 May 2021].

Hassenzahl, M. & Tractinsky, N., 2006. User Experience – a Research Agenda. *Behaviour and Information Technology,* March-April, 25(2), pp. 91-97.

Hopkins, R., 2008. *The transition handbook: From oil dependency to local resilience.* UK, Totnes, Devon: Green Books.

Huotari, K. & Hamari, J., 2012. *Defining gamifica- tion – a service marketing perspective.* Tampere, Proc 15th MindTrek conference, pp. 17-22.

Ingle, B. R., 2013. *Design thinking for entrepreneurs and small businesses: Putting the power of design to work.* New York, NY: Apress.

ISO, 1998. *Ergonomic requirements for office work with visual display terminals (VDTs).* s.l. Patent No. 11: Guidance on Usability.

ISO, 2001. *Software engineering - Product quality.* s.l. Patent No. 1: Quality model.

ISO, 2008. *Ergonomics of human-system interaction.* s.l. Patent No. 171: Guidance on software accessibility.

ISO, 2008. *Ergonomics of human-system interaction.* s.l. Patent No. 210: Human-centred design process for interactive systems.

Kleinsmann, M. & Valkenburg, R., 2008. *Barriers and Enablers for Creating Shared Understanding in Co-Design Projects.* s.l.:Design Studies.

Kujala, S., 2003. *Behaviour and Information Technology.* s.l.:s.n.

Lawson, B., 2006. *How Designers Think: The Design Process Demystified.* 4 ed. Amsterdam: Elsevier.

Lee, Y., 2008. Design participation tactics: the challenges and new roles for designers in the co-design process. *Co-design,* 4(1), pp. 31-50.

Leimeister, J., 2012. *Dienstleistungsen- gineering und -Management.* Berlin: Springer Gabler.

Lutzke , L., Drummond, C., Slovic, P. & Árvai, J., 2019. Priming critical thinking: simple interventions limit the influence of fake news about climate change on Facebook. *Global Environ. Change,* 58(101964).

Mäkelä, A. & Fulton Suri, J., 2001. *Supporting Users' Creativity: Design to Induce Pleasurable Experiences.* s.l., Proceedings of the International Conference on Affective Human Factors Design, pp. 387-394.

Malewicz, M., 2020. *Glassmorphism in user interfaces.* [Online] Available at: https://uxdesign.cc/glassmorphism-in-user-interfaces-1f39bb1308c9 [Accessed 12 May 2021].

Maslog, C., 2020. *Asia's public transport systems limit social distancing.* [Online] Available at: https://www.scidev.net/asia-pacific/column/asia-s-public-transport-systems-limit-social-distancing/ [Accessed 12 May 2021].

Mitchell, V., Ross, T., Sims, R. & Parker, C. J., 2015. *Empirical investigation of the impact of using co-design methods when generating proposals for sustainable travel solutions.* s.l.:s.n.

Nguyen, D., 2020. *HCMC bus service fails to attract more passengers despite increased subsidy.* [Online] Available at: https://e.vnexpress.net/news/business/companies/hcmc-bus-service-fails-to-attract-more-passengers-despite-increased-subsidy-4120200.html#:~:text=HCMC%20bus%20service%20fails%20to%20attract%20more%20passengers%20despite%20increased%20subsidy,-By%20Dat%20Ng [Accessed 12 May 2021].

Nokia Corporation, 2005. *Inspired Human Technology.* [Online] Available at: http://www.nokia.com/NOKIA_COM_1/About_Nokia/ Press/White_Papers/pdf_files/backgrounder_inspired_h uman_technology.pdf [Accessed April 2021].

Petkov, P. et al., 2011. *Engaging energy saving through motivation-specific social comparison.* Vancouver, Proc conference on human factors in computing systems, pp. 1-6.

Richardson, A., 2010. Using customer journey maps to improve customer experience. *Harvard business review,* 15(1), pp. 2-5.

Rijn, H. v. & Stappers, P. J., 2008. Expressions of ownership: Motivating users in a co-design process. *PDC,* Volume 8, pp. 178-81.

Rohracher, H., 2005. *User Involvement in Innovation Processes: Strategies and Limitations from a Socio-Technical Perspective.* Munich: Profil Verlag.

Sanders, E. B. N. & Stappers, P. J., 2008. *Co-Creation and the New Lanscapes of Design.* s.l.:CoDesign 4.

Seidel, M., Loch, C. & Chahil, S., 2005. Quo Vadis, Automotiven Industry? A Vision of Possible Industry Transformations. *European Management Journal,* 23(4), pp. 439-449.

Staricco, L., 2013. Smart Mobility, opportunità e condizioni. *Tema-Journal of Land Use; Mobility and Environment,* Volume 3, pp. 289-354.

Steen, M., 2011. *Tensions in Human-Centred Design.* s.l.:CoDesign 7.

Steen, M., 2013. Co-Design as a Process of Joint Inquiry and Imagination. *DesignIssues,* 29(Design), pp. 16-28.

Steen, M., Manschot, M. & Koning, D. N., 2011. Benefits of co-design in service design projects. *International Journal of Design,* 5(2), pp. 53-60.

Väänänen-Vainio-Mattila, K., Roto, V. & Hassenzahl, M., 2008. Towards practical user experience evaluation methods. *Meaningful measures: Valid useful user experience measurement (VUUM),* pp. 19-22.

Vartiainen, J., 2012. Helsinki, InfraExpo 2012 seminar.

Vos, E. P., Maiheu, B., Vankerkom, J. & Janssen, S., 2013. Improving local air quality in cities: to tree or not to tree?. *Environmental pollution,* Volume 183, pp. 113-122.

Vosoughi , S., Roy, D. & Aral, S., 2018. The spread of true and false news online. *Science ,* 359(6380), pp. 1146-1151.

Wang, Q. Y. et al., 2006. The role of psychological ownership and ownership markers in collaboratve working environment. *ICMI'06.*

APPENDIX 1

Game-design elements and motives (adapted from Blohm and Leimeister 2013, 276)

Game-design elements		Motives
Game mechanics	Game dynamics	
Documentation of behavior	Exploration	Intellectual curiosity
Scoring systems, badges, trophies	Collection	Achievement
Rankings	Competition	Social recognition
Ranks, levels, reputation points	Acquisition of status	
Group tasks	Collaboration	Social exchange
Time pressure, tasks, quests	Challenge	Cognitive stimulation
Avatars, virtual worlds, virtual trade	Development/organization	Self-determination

APPENDIX 2

Understanding Climate Action Survey

General questions:

1. Email address
2. First name
3. Last name
4. How old are you?
   - ○ Under 20 years
   - ○ 20-39 years
   - ○ 40-59 years
   - ○ 60 years and above
5. What is your gender?
   - ○ Male
   - ○ Female
   - ○ Prefer not to mention
6. Which country are you residing in?
   - ○ Singapore
   - ○ Malaysia
   - ○ Cambodia
   - ○ Indonesia
   - ○ Thailand
   - ○ Vietnam
   - ○ Brunei
   - ○ Myanmar
   - ○ Philippines
   - ○ Laos
   - ○ China
   - ○ India
   - ○ other

7. Do you own a vehicle?
   - ○ Yes
   - ○ No
   - ○ Not anymore
8. Which mode of transportation do you usually commute on?
   - ○ Personal vehicle (car/motorcycle)
   - ○ Public transport (bus/train)
9. Do you have any environmental-related apps on your mobile phone?
   - ○ Yes (bring to next question)
   - ○ No

(follow up from q6.) What is the name of the environmental-related app?

(follow up from q7.) What was your purpose of downloading the app?

10. Do you feel there is any social impact of using this app?
11. Are you aware of the consequences brought about by climate change?
    - ○ I am aware
    - ○ I am slightly aware
    - ○ I am not aware
12. Do you actively read up on climate-related news?
    - ○ yes
    - ○ sometimes
    - ○ not at all
13. Do you think climate action is important?
    - ○ yes
    - ○ no
    - ○ maybe
14. Do you support climate action?

Climate action means stepped-up efforts to reduce greenhouse gas emissions and strengthen resilience and adaptive capacity to climate-induced impacts, including but not limited to: climate-related hazards in all countries; integrating climate change measures into national policies, strategies and planning; and improving education.

- ○ I support the cause

- ○ I do not support the cause

Are you consciously aware of your everyday actions to combat climate change?

- ○ I am conscious of my everyday actions (e.g.: I refuse to use plastic straws)
- ○ I am slightly conscious of my everyday actions (e.g.: I occasionally refuse to use Plastic straws)
- ○ I go about my normal daily lifestyle

(follow up from q17.)

15. Share with us what motivates you to continue doing so? (open-ended)
16. Do you donate to or volunteer for any environmental charities and organizations?
    - ○ yes
    - ○ no
    - ○ sometimes
17. Do you check the air quality of your area?
    - ○ yes
    - ○ no
    - ○ sometimes
18. I would track the air quality of my area as, (can select more than one)
    - ○ It concerns my health
    - ○ I want to play a part in ensuring healthy air quality
19. Would you be interested in an app that tracks your carbon footprint for transportation?
    - ○ yes
    - ○ no
    - ○ maybe
20. What would motivate you to use an environmental-related app?
    - ○ the features within the app

    (heatmap-airflow visualization, carbon footprint scoreboard)
    - ○ health benefits
    - ○ incentives/rewards (travel vouchers, cashbacks, and ecommerce perks)
    - ○ others: (please state)