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Maxine Mathijssen, Maureen Tanner

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The use of a user-centric smart mobile application prototype for supporting safety and security in a city: A design science method

Maxine Mathijssen
University of Cape Town, Cape Town South Africa
MTHMAX005@myuct.ac.za

Maureen Tanner*
University of Cape Town, Cape Town, South Africa
mc.tanner@uct.ac.za
0000-0001-9230-7672

Abstract: Cities are the drivers of innovation, growth, and change, and are rapidly expanding, especially in Africa. Cape Town is one of those cities, with high urbanization rates and persisting crime levels. There is a need to design 'smart' ways of growth which includes facilitating a safe and secure city for citizens. This study focuses on smart city initiatives in Cape Town, placing citizens at the center of the development process. Crowdsourcing techniques are utilized to develop a smart mobile application prototype that focuses on enhancing community engagement, resilience and increased perceived feelings of safety and security for citizens. The study uses a Design Science Research method with Cape Town citizens as the main stakeholders, to propose an artifact based on their wishes and needs with regards to safety and security in the city.

Keywords: Smart City, Cape Town, mobile application, safety and security, community.

1. Introduction

Cities have always been the drivers of innovation, growth, and change [1]. Urban populations are rapidly increasing, and interestingly, 95% of urban expansion are expected to take place in developing countries on the Asian and African continents [2]. As urbanization rates in these countries are high, there is a growing demand to relieve pressure off urban areas, facilitate economic growth and improve safety and security for citizens [3]. Smart city technologies are a potential solution to urbanization-related issues and are furthermore argued to attract new business and city investments, create job opportunities, and improve productivity [4]. Smart cities are usually argued to deploy Internet of Things (IoT) and Information and Communication Technologies (ICT) to connect information, people, and city elements for the benefit of creating a better manageable, sustainable, and livable city, while maintaining a competitive edge [1]. To facilitate this, a smart city is dependent on its citizens and participatory governance and should take a user-centered approach as it is focused on enhancing livability [5].

Although investigated quite extensively across Western and Asian contexts [6], smart city concepts have remained relatively unexplored within developing countries on the African continent, despite African cities' attempts to pursue smart city agendas (see [7]). As there is no one-size-fits-all model, smart city implementations across Western or Asian countries cannot simply be duplicated to apply to African cities.

Developing countries are characterized by rapid urbanization, social and economic inequality and high urban crime rates [7,8]. Research has shown that when pursuing smart city developments, developing nations have not focused enough on delivering a 'smart and safe' city that fights crime and ensures public safety for its citizens [8–11]. An inclusive and safe city should be a prime focus when addressing smart city strategic developments, especially in developing countries [8]. In the longer run, a safe and secure city environment is critical for a smart city that wants to be sustainable and attract foreign business and investments [12].

Therefore, this study adopts community-based, crowd-sourcing approach to technology design, that is focused on increasing perceived safety and security of citizens in developing cities. The focus is on developing countries that are characterized by high urbanization rates, high urban crime rates and fear of crime. One such smart technology is the use of mobile applications for the benefit of smart urban development. Literature has increasingly covered the role of mobile services in harnessing safety and security of citizens in the urban context (see [13,14]). Studies show that people are willing to download safety apps that include live tracking capabilities [15], reliability and transparency in terms of where data is stored, and functionalities that allow users to send emergency signals to loved ones [16] to enhance perceived feelings of personal safety [17]. Furthermore, personal safety apps are argued to be usable to the community because they are local and belong to the citizens as the end users [16].

In developing smart technologies, citizen involvement is unmissable, as establishing trust amongst citizens is a key factor to ensure the success and longevity of the ecosystem [8]. This research aims to design a proof-of-concept smart mobile application that focuses on increasing feelings of safety and security of citizens in the urban, smart city context. This smart mobile application falls within the realm of a smart city application. The implementation of smart city application is characterized by requirements related to communication, information sharing and real-time information [49]. The proposed smart mobile application will abide by these three characteristics. The research takes Cape Town as its case study, which is South Africa's third largest city with approximately 3.7 million residents and argued to be the crime capital of South Africa, while furthermore ranking as one of the world's highest in terms of homicide rates [8,18]. Western Cape crime rates are the highest and fastest growing in the country, making crime prevention and control a concern and high priority for city management [12] to which this research aims to contribute.

To strive towards a city that is perceived safer by citizens, this research offers an alternative perspective that takes on a user-driven approach for developing a smart mobile application prototype with the aim of increasing perceived feelings of safety and security. This approach is taken on using a Design Science Research (DSR) methodology, which is realized through creating an artifact with the goal of solving practical problems, which here relate to disproportionately high crime rate and increased perceived feelings of a lack of safety and security among citizens.

The following research question is introduced: How can a 'smart' community-based crime-focused mobile application influence feelings of safety and security for Cape Town citizens?

The study aims to contribute to research and practice by applying results from the case to cities on the continent with similar urban characteristics and developmental traits to expand knowledge on smart city developments across the African continent. In doing so, this research takes on a user-centric approach aiming at addressing, understanding, and detailing the needs and wishes of citizens with regards to fear of crime and feelings of safety and security in the context of a smart city.

As mobile phone penetration is high across the continent and access to Internet is rapidly expanding, a mobile prototype ought to contribute to research and practice by introducing a smart application that is accessible to its users. As the mobile prototype proposed in this research aims to use crowdsourcing and is dependent on user input as well as existing crime-related city data, the prototype provides a technology intended to facilitate greater community engagement and feelings of safety.

2. Literature Review

2.1. Smart Cities

The United Nation Population Fund states that since 2008, more than half of the world's population lives in cities and this percentage is expected to rise to 70% by 2050 [19]. Growing cities bring challenges that local authorities need to respond to. Such challenges are concerned with public safety and security, quality of living, public transportation and infrastructure, employment and economy and environmental performance [20]. As a result, questions arise with regards to how a city could be "smart" and designed in such a way that the implementation of technologies can facilitate public safety and security for citizens thereby positively impacting the overall quality of living [21].

It is commonly argued that a smart city is an urban area that deploys IoT and ICT for the benefit of creating a better manageable, sustainable, and livable city, while maintaining a competitive edge [1,22]. Smart cities commonly focus on a variety of dimensions, such as safety, economy, people, governance, mobility, environment and living, and comprises of people, businesses, organizations, and processes to achieve the desired goals for the city [23]. The end goal of a smart city is to increase quality of living for citizens and deliver benefits for governments on a national and provincial level, as well as for local city-level municipalities [6]. The use of smart mobile devices such as smartphones and wearables, is rapidly increasing and form a huge potential for future smart cities designed at meeting citizens' demands [24], which is the focus of this study.

Previous studies have explored the wide variety of smart city applications, which include smart energy, smart public services, smart water and waste management, smart mobility, and smart security, amongst others [25]. Smart city applications are necessary for communication and sharing of real-time information that facilitate the implementation and growth of the smart city [25]. This study focuses on one area of smart city applications, which is that of smart security.

2.2. The City of Cape Town and the smart city

Cape Town is the second largest city in South Africa with approximately 3,4 million inhabitants and an important center for trade, especially with respect to tourism and the mobile IT sector [8]. In 2002, the City of Cape Town launched their "Smart City Strategy", as part of the wider City Development Strategy (CDS) for Cape Town. The focus of the strategy included leadership, policy and regulation, e-government, IT enabled development and IT enabled governance [2]. A decade later, the Integrated Development Plan was launched, serving as a five-year strategic framework that guides decision making within the municipality [2]. The plan was built around five 'pillars' which include the opportunity city, the safe city, the caring city, the inclusivity city and the well-run city [2]. The city has recently improved internet speed

and overall access, introduced the use of digital platforms for access to digital public services, and opened data sources for utilization by businesses [2]. However, it is the ‘safe city’ pillar that this study aims to explore further. There is a need to develop smart city objectives in Cape Town involving the city’s population in project planning and implementation. This research aims to further built on existing literature and applications for enhanced inclusivity and contributing to technological advancements that are community-based and use crowd-sourcing solutions in the context of a smart city.

2.3. Safety and security in Cape Town

Public safety and security are highly intertwined with crime rates, in such that they are compromised when city crime rates are high, and cities are not actively putting in measures to combat crime [26]. Especially in developing countries, where resources for combating crime are generally less widely available than in developed countries, deterring crime and realizing a safe and secure city is one of the main objectives for a smart and safe city [27].

In South Africa, crime cases are a national health priority as the country reports a six times higher homicide rate than the global average [18]. Recent official statistics show that Western Cape crime rates are the worst in the country and in many categories identified by South African Police Services (SAPS) [28].

Considering the above-mentioned points, there is a need for urban integration that is inclusive and focuses smart developments around addressing safety and security related issues at the level of citizen’s wishes and needs, which will aid cities to function better through distributed problem-solving decisions [25,29]. The safe city must be considered vital for enhancing effective city management, handling crime, and facilitating a healthy living environment for citizens [30]. Various research has explored interventions in developing countries that seek to support safety by improving old systems using smart technologies (e.g., [31,32]). However, it is important to gauge how citizens perceive urban security to promote smart city management. This not only prevents or responds to safety concerns, but also ensure a that the city is an attractive place to reside in [30]. Smart safe applications in urban spaces are crucial and help improve urban governance and planning as well as provide a better living environment for citizens [30].

2.4. Personal Safety and Fear of Crime

Most studies acknowledge the relationship between personal safety and crime, both of which have significant theoretical and empirical commonalities [33]. Like crime committed against an individual, personal safety is said to be jeopardized when intentional harm is being done to an individual or their property [34]. Said, then, is that the perception of personal safety is threatened by a fear of crime [35]. Some research identifies that fear of crime occurs when people can imagine themselves falling victim to crime, partly because of hearsay from people they know [36]. In addition, fear of crime is fed through physical environmental factor such as poor lighting, hiding places for criminals, poor state of buildings, and a high frequency of abandoned streets within areas, as well as social factors such as the lack of police control, surveillance cameras and people in the street/area [37].

Previous research shows that providing crime related information to citizens and involving them in effective policing is assumed to be socially beneficial and leads to better public service transparency [13, 38]. Although a ‘safe city’ constitutes one of the five pillars for city development in Cape Town according to the IDP [2], it is commonly argued that citizen involvement by authorities for the benefit of safer cities has been lacking [38]. As a result, this research aims to involve end-users in the development of a mobile application prototype that attempts to increase community involvement and empowerment, as well as increased feelings of safety and security, partly because of reduced fear of crime and victimization.

2.5. Citizen involvement and user-centered design

Smart cities are first and foremost associated with the implementation of a set of technologies for the benefit of a livable city [39]. However, various research has argued that smart city applications often put too much focus on just the technologies, and less on citizens and engagement with society [22], while communities and individuals should be considered as key stakeholders in the smart planning process [22]. The danger of failing to consider citizens and societal engagement in these applications could result in wasting expenditures that were initially budgeted to facilitate the implementations [22]. In addition, the leverage of smart technologies is often provided by corporate giants, regularly leading to monopolization of the smart city because of a shift in power dynamics from the city to corporate companies [22]. Consequently, smart cities could lose their creative edge [1]. For this reason, a design science research method is explored in this research, where end-users are placed at the center of the development process and new knowledge is created from the lived experiences, wishes, and needs from end-users.

3. Methodology

3.1. Research strategy

A qualitative research method was chosen for this research to assist in the elicitation of the requirements for the application. This was relevant as this study is aimed at understanding the “lived experiences” and perceptions of people

to gain a deeper understanding of the problem at hand and gaining insights from its meaning [40]. These insights then form the basis of constructing the prototype, for which creativity and co-creation are the most important values.

3.2. Design Science Research methodology framework

This study uses the DSR methodology. DSR is defined as “the scientific study and creation of artifacts as they are developed and used by people with the goal of solving practical problems of general interest” [40]. The artifact that is developed during the study is a mobile application prototype. In answering the research questions using a DSR method, the research draws on the methodological framework from [40]. The different stages of the design science method framework are addressed in the next subsections.

3.2.1. Activity 1 - Explicate problem. To define the requirements for building the mobile application prototype, the problems must be defined precisely [40]. To achieve this, interviews with respondents were held in line with DSR, with the purpose of identifying lived experiences of the participants in relation to their current safety and security-related challenges. To achieve the above, a total of 12 semi-structured interviews were conducted. More details about the interviews, how they were conducted and how their results were analyzed are described in the data collection section.

3.2.2. Activity 2 - Define Requirements. Where the previous activity elicited the problem, this stage evaluated the application requirements as proposed by the stakeholders and assessed their completeness and feasibility for implementation [40].

3.2.3. Activity 3 - Design and development of artifact. The third activity is Design and Develop Artifact with the aim of fulfilling the requirements as proposed in the previous stage. This activity was concerned with “creat[ing] an artifact that addresses the explicated problem and fulfils the defined requirements” [40] (p.117). The input used in this stage consisted of the insights gathered from the participants and knowledge from literature. This phase comprised of three sub-activities. In the first sub-activity, a brainstorm session was conducted, leading to the design of sketches for the user interface. The second sub-activity included a more elaborate design of the mobile application prototype. Use case diagrams and user stories were used to visualize the skeleton of the prototype with its main functionalities and actors. Lastly, in the third and final sub-activity, the prototype was designed using the software Sketch which was used to demonstrate the artifact, and to obtain user feedback in the evaluate artifact phase.

3.2.4. Activity 4 - Demonstrate artifact. The aim of this phase was to demonstrate the mobile application prototype that had been designed in the previous phases [40]. In this phase, descriptive insights were gathered from participants, by asking them to engage with the prototype through user stories describing real-life scenarios. Each user story contained one or more acceptance criteria, which were in line with the application. The user stories defined how the application was expected to behave and how these behaviors should be satisfied.

3.2.5. Activity 5 - Evaluate artifact. This activity determined how well the artifact solved the explicated problem and how well it satisfied the requirements set out in the second stage. In this phase, participants were interviewed and asked for their feedback after which alterations were made to the artifact accordingly. Four users from the initial pool of participants were asked to participate in the second round of interviews in which they were given access to the prototype and asked to carry out a set of tasks (activity 4). semi-structured interviews were then conducted, guided by the Technology Acceptance Model for evaluation.

The research used Davis’ TAM as a model as theoretical underpinning for gathering and analyzing user feedback on the mobile prototype during the evaluation phase [41]. TAM is one of the most widely used models for user acceptance and use of technology in the Information Systems field [42].

The model assumes that users come to accept a technology when there is a high level of Perceived Usefulness (PU) and Perceived Ease of Use (PEU) of the technology [42]. This study assumes that PEU is achieved when the user of the application believes that using the smart city mobile application prototype would be free of effort. PU refers to the user believing that the smart city mobile application prototype would enhance their feelings of safety and security in the city. PU and PEU are the most important factors in determining an individual’s attitude towards the system and whether they will use it [43].

Participants were asked to perform a set of tasks, in line with the system’s main functionalities. These tasks are identified as the external variables for evaluating the technology’s acceptance by the interviewees. The following external variables were chosen:

- Task 1: Create a new account and log in
- Task 2: Start a safe route
- Task 3: File an incident report
- Task 4: Become member of a community
- Task 5: Add a safety resource to your folder
- Task 6: Send out an emergency signal

Incorporating the task assessments into the technology acceptance model for evaluation, the research proposes an applied TAM (see Figure 1). The following section addresses how this model was used for artifact evaluation.

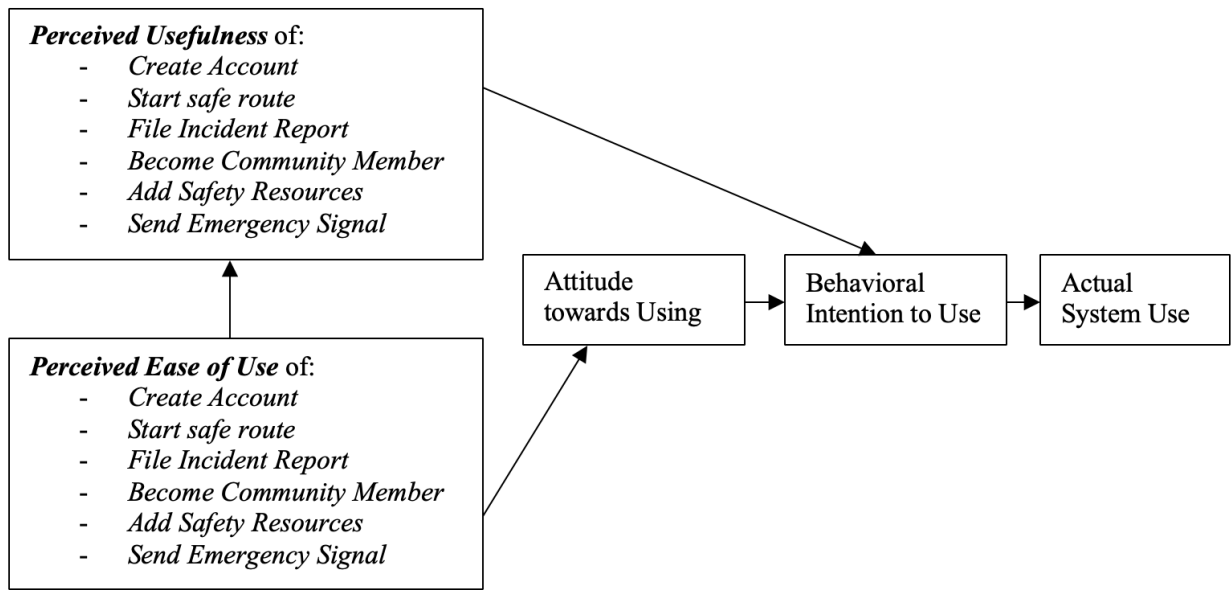


Figure 1. Technology acceptance model for evaluating smart mobile application prototype - adapted from [41]

3.3. Sampling strategy and size

The overarching sampling method used in this research is that of nonprobability purposive sampling. The strategy chosen is purposive in nature, because it does not involve random selection of participants and the study aims to include participants from the different strata identified. Within the purposive sampling method, the study specifically utilized nonproportional quota sampling. In quota sampling, the population, in this case Cape Town’s population, is divided into strata which are relevant to the study’s topic of interest. The strata chosen for the quota sampling in this study include gender and location. These strata are considered most important for evaluation based on previous literature on crime, safety and security in the context of Cape Town as a smart city (see [45]). Literature suggests women are less likely to defend themselves against perpetrators and further experience higher fear of crime than their male counterparts [50], hence why gender is chosen as a stratum. To determine the difference in perceptions of safety across the city and success of the application, location is chosen as the second stratum for sampling.

The total number of respondents during the first round of interviews is N = 12. The sample overview can be found in Table 1.

Table 1. Sample overview interviews round 1

Respondent No	Gender	Living location	Age	Race	Home-work travel method	Access to Phone	Access to internet
R1	Female	Observatory	27	White	Walking	Yes	Yes
R2	Female	Central Business District	28	Black	Private car	Yes	Yes
R3	Male	Observatory	25	Black	Private car	Yes	Yes
R4	Male	Sea Point	25	White	Private car	Yes	Yes
R5	Female	Sea Point	25	White	Private car	Yes	Yes
R6	Female	Kenilworth	21	Asian	Private car	Yes	Most of the time
R7	Male	Woodstock	29	Black	Public transport	Yes	Yes
R8	Female	Salt River	24	White	Walking	Yes	Yes
R9	Female	Observatory	24	White	Public transport	Yes	Yes
R10	Female	Rondebosch	26	Black	Public transport	Yes	Yes
R11	Male	Green point	28	Black	Public transport	Yes	Yes
R12	Male	Salt River	30	Black	Walking	Yes	Most of the time

The total number of respondents during the second round of interviews is N = 4 (see Table 2). After that, data saturation was reached. Respondents kept their case number from the first round of interviews.

Table 2. Sample overview interviews round 2

Respondent No	Gender	Living location	Age	Race	Home-work travel method	Access to Phone	Access to internet
R4	Male	Sea Point	25	White	Private car	Yes	Yes
R6	Female	Kenilworth	21	Asian	Private car	Yes	Most of the time
R8	Female	Salt River	24	White	Walking	Yes	Yes
R11	Male	Green point	28	Black	Public transport	Yes	Yes

3.4. Data collection method

Interviews were chosen as the preferred data collection method as they allow for high engagement with respondents and facilitate greater creativity which are important objectives for development of the prototype. Rounds of interviews were performed twice, during the first stage and fifth stage of the design period, in the explicating problem and artifact evaluation stage, respectively. Interviews were conducted via WhatsApp because of the Covid-19 restrictions active at the time of data collection. All interviews were recorded. Additionally, field notes were taken by the researcher during the interviews.

3.4.1. Interviews round 1. As the research follows the DSR method, the main purpose of the interviews was to go into depth on the lived experiences of users and consequently get an understanding of the problem. In the first part, respondents were asked general questions addressing demographic characteristics, namely age, gender, race, housing status, place of residence, job status and employment location, work-home travel method, income, access to mobile device and access to the Internet. Thereafter, the research focused on gathering individuals' perception of crime threat, perceived safety in the neighborhood, trust in local crime prevention authorities, and degree of neighborhood integration. Participants are encouraged to openly share their experiences with regards to feelings of safety and security in the city and their neighborhood.

In the second part of the interview, participants were informed about the proposed design of a mobile application prototype and its function as a smart city application that is focused on enhancing feelings of safety and security of Cape Town citizens. The notion of a smart city was explained in the interview. Participants were asked to share their wishes and needs when it comes to enhancing feelings of safety and security through mobile application prototype features and requirements. Particularly, the participants are asked to translate their experiences with regards to safety and security threats as identified earlier in the interview and fit them within a set of requirements to enhance their feelings of safety and security.

Lastly, participants are asked how they foresee the success of a prototype with the purpose of enhancing citizens' feelings of safety and security, which potential drawbacks could be identified.

3.4.2. Interviews round 2. Following the DSR method, a second round of interviews was performed during evaluation stage. The purpose of the second round of interviews was to gather feedback from participants on the developed prototype and to what degree it conformed to the participants' expectations with regards to feeling safe and secure in their neighborhoods in Cape Town as set out in the initial round of interviews. The in-depth interviews provided rich insights in the perceived usefulness and ease of use of the artifact. Furthermore, because of the structure and determined content of the interview protocol, saturation of knowledge could be reached after these interviews.

The mobile application prototype was made available on Sketch cloud. The participants interviewed for the in-depth evaluation were sent an open link to the prototype. The prototype was made available to interviewees just before the start of the interview. Participants were asked to open the link on their mobile device to have the best mobile application prototype experience, while keeping the interview call on loudspeaker.

During the first part of the interview, participants were given the opportunity to explore the different screens to get an impression of the general look and feel of the prototype as well as the available screens and menu options. Participants were asked to provide comments on their first impression. During the second part of the interview, participants were requested to perform a set of six tasks derived from the main use cases. The protocol for the task assessment and evaluation follows the Technology Acceptance Model, where users were asked to assess intention to use and ease of use for each of the tasks. The six tasks were the same for each of the participants to facilitate comparison and implement any feedback accordingly. In addition to commenting on the perceived usefulness of the different system functions, participants were further asked to specifically assess the perceived usefulness of the system functions in terms of its effect on enhancing feelings of safety and security.

3.5. Data analysis

All interviews were transcribed. The approach chosen for qualitative data analysis is that of thematic analysis (44). Specifically, this research engaged in inductive thematic analysis. As the design science research method aims to generate new knowledge, insights, and explanations from the perspectives of users central to the problem, inductive thematic analysis was performed to refrain from fitting the data in a pre-existing frame, but rather linking the themes to the data themselves.

NVivo was used to analyze the qualitative data gathered in the interviews. Coding of the interviews was performed in two phases. The first phase included the coding of the first half of the interview, going into challenges with regards of feeling safe and security in the neighborhood and the city. This part is called “Perceptions of safety” and a total of 16 nodes were used to code this section. Nodes were subdivided into the following themes: challenges influencing safety and security, attitudes towards safety, neighborhood development, and external factors impacting safety.

The second phase included the coding of the second part of the interview, going into wishes and needs with regards to enhancing safety and security in the neighborhood and the city in the context of the mobile application prototype development. This part is called “Wishes and needs” and total of 14 nodes were used to code this section. Nodes were subdivided into the following themes: Application requirements, attitudes towards using the app, challenges for using the app, and factors impacting use and success of the app.

The second round of interviews, in which four participants were interviewed to obtain feedback on the developed mobile application prototype as a result from the requirements deriving from the first round of interviews, have been coded into a code book called “Application Evaluation”. A total of 10 nodes is used to code this section.

4. Findings

4.1. Explicate Problem – Challenges with regards to feelings of safety and security

This section discusses the results from the first part of the interviews. The participants’ challenges are discussed with regards to their feelings of safety and security in the neighborhood.

4.1.1. Fear of night-time. The first challenge experienced by interviewees that negatively impact feelings of safety and security for participants relates to the daytime versus night-time divide. All people interviewed identify that they feel less safe or completely unsafe at night in their neighborhood. The reasons for the feelings of unsafety at night-time range from a lack of visibility in their surroundings, streets becoming quieter and a feeling of vulnerability: *“Times I feel unsafe would definitely be when it gets darker, at nighttime, because the roads generally become more quite in Sea Point, so I feel more vulnerable, less safe”* [R5].

4.1.2. Mode of transportation restrictions. Respondents mention mode of transportation as a factor impacting their feelings of safety in their neighborhood, leading to a decrease in feeling safe and secure. The respondents with access to a car stress that driving a private car gives them a safe or safer feeling because it is a personal space that is not likely to be compromised. Taxi services such as Uber are perceived somewhat safe by those respondents that use this mode of transportation. However, in a few cases, these private taxi services are also considered unsafe: *“I’m okay with using an Uber but there are sometimes some issues with Ubers attacking females or kidnapping people or stuff like that. So, I’d rather just use my own car most of the time”* [R2]. Some respondents also stated they feel uncomfortable whilst using public transport as it limits the possibility of being in one’s own space. Word-of-mouth pertaining to the risks associated with public transport also limit their feelings of safety and security. Lastly, walking decreases respondents’ feeling of safety, especially while carrying valuables: *“I would walk and I would see weird people following me and I would literally have anxiety attack due to that, because I would never feel safe knowing that there is somebody potentially following me and if there is nobody in the street and then also it does really affect me”* [R9].

4.1.3. Feeling unsafe around strangers. The third challenge relates to feelings of unsafety around strangers: *“So at night when I see maybe a group of men, usually, I feel less safe. And then safer if I see couples, or groups of all kinds of different people who don’t look poor, then I feel safer, I guess, to be honest”*. Respondents mention that they feel safe(r) when there are more people around (e.g., in shopping centers, the promenade, and beaches). Touching upon feelings of unsafety, respondent R2 mentions that the presence of beggars gives her an increased feeling of unsafety: *“There is a lot of them around in the area, especially by our apartment block there is a lot of people always begging and stuff. You never know their real intentions. Because some of them might want to steal but some of them might really actually be begging for food innocently”*.

4.1.4. Street architecture and infrastructure. The fourth challenge relates to the design of the streets and overall infrastructure. For instance, open and visible spaces, proper streetlights, greenery, the presence of bars and restaurants, and cleanliness of the area contribute to increased feelings of safety and security: *“If you look at Camps Bay there is a lot of visibility, it’s a big suburb, there is greater infrastructure there and the lights and patrols are higher”* (R7). The inability to look far ahead also diminishes participants’ feelings of safety: *“I feel like in Observatory, there is a*

main road and there are a lot of street corners and as soon as I'm approaching a corner I'm always stressing out, because there is a lot of stories where people are hiding in these small streets and waiting for victims and attack them as soon as they cross the corner" [R3].

4.1.5. Lack of police support and follow-up. The fifth challenge identified by interviewees refers to the lack of police involvement and follow up when incidents are reported: *"when we had the break in, we literally investigated on our own and we found out who did it through the body corporate, the building managers, and we found pictures of the person who did it. We literally told the police that we have pictures, but they didn't do anything with the case and didn't get back to us like they said they would"* [R2].

4.2. Define Requirements

This section addresses the application requirements as proposed by the interviewees, with each requirement discussed in a different sub section linking back to the challenges with regards to feelings of safety and security for participants in the study.

4.2.1. Emergency panic button. All participants mentioned the need for an emergency button. How this functionality should function was dependent on the respondent. Overall, most respondents conclude that the emergency panic button should be easily accessible and easy to navigate, as the respondents mention such a functionality would be ideal to use in case of emergency: *"I think that I would probably at the top of my head want something like a panic button, something that I can react to really quickly in instances where I am being attacked, or somebody is trying to attack me, or somebody is trying to rape me"* [R2]. With regards to the easy navigation of such a functionality, because of time constraints in a situation of emergency, two participants came up with the idea of a "hot key" or "assistive touch" which sits on the screen when it is locked: *"I guess basically having an always on function to the app where it's kind of sitting on your screen whether or not the phone is locked or unlocked so you can press it in a panic situation"* [R3]. Another participant proposes a code word functionality that listens only to the person owning the device: *"So you for example choose your own code word and no one else also knows it. And then whenever you use that, or you have to say it twice so something like that, it activates"* [R8].

Among participants, there was no consensus on who should be buzzed once the emergency button has been activated. The range of options includes family members or friends, neighborhood watch, private security companies, and local police officers. For most of the participants, the signal should preferably go out to the security (community) team nearest to the destination of where the emergency has been reported, so a fast response is guaranteed: *"Depending on which area you're on, it sends a signal to community safety or police that are in that area, I think that would be the most valuable feature that the app would have"* (R3). The mobile app emergency button could be linked to physical emergency buttons installed in homes, so it is accessible through the mobile device anywhere and at any moment. Such a functionality relates back to the challenge of time of day, and specifically, a fear of night-time, fear of strangers, challenges relating to certain modes of transportation, and feeling unsafe in certain streets and areas: *"If you don't feel safe at a particular occasion, you click help and then it alerts a security team that patrols in the area to come to your location to escort you to wherever your destination that you would like to reach. So, I think that's one of the important things"* [R10].

4.2.2. Crime heat map. The second requirement for the app was that of a crime heat map which enables citizens to log incidents and suggests neighborhood to be avoided and accessed based on previously logged information: *"I think it would be really helpful, a crime heat map, because some instances you want to go somewhere but you are not necessarily sure what the crime rate is like there because you've never been there before. So, I think it would be really helpful and it wouldn't really scare me"* [R2]. Some participants suggested that the logged incidents be filed in a database which would be used to make long term algorithms available for safe route planning for citizens, as well as being able to (re)allocate law enforcement resources to those areas identified as crime hotspots to tackle and diffuse criminal activity.

Flowing from the idea of a crime heat map was the suggestion for a safe route planning system. Some participants indicated that planning a route in the app could be relevant to avoid certain areas that are associated with high crime and incidents. Participants would be able to enter their destination point and be directed towards their destination in the safest manner, building on logged incidents from the crime heat map.

Such a safe route planning system, building on the crime heat map, could primarily tackle the time of day and mode of transportation challenge faced by participants: *"Like maybe trends can be developed from that, so let's say all incidents are happening between 10 at night and 2 am, then you're kind of like it's just not a good idea to walk at night whether you're in a group or alone"* [R5]. A crime heat map could also recommend where to drive and park a car safely: *"I think for a long-term thing it's definitely positive for them to track down if there has been car break in"* [R1].

4.2.3. Community chat room. A third requirement suggested by participants related to a community chat room, to enable the user to speak to people in the neighborhood or obtain updates: *"People can post updates (...) or if I see something sketchy and I'm just going to ask on the app like "did anyone else see this? I would just like to clarify that"*

Table 3. Use cases, user stories and example acceptance criteria

Use Case	User Story	Example acceptance criteria
Login	I would like to sign into my account so that I can access my personal app.	Given that I am a returning user, when I open the app, I expect to be able to log in with my email and password credentials, so that I can access my personal app.
Reset Password	I would like to reset my password so that I can log in to my account even if I forgot my password.	Given that I am a returning user, when I try to log in but cannot remember my password, I expect to reset my password, so that I can log in.
Create Account	I would like to create a new account so that I can use the app when I am a new user.	Given that I am a new user, when I am a new user, I expect to have a clearly visible “sign up” button at the bottom of the screen so that I can create a new account.
Create Account	I would like to see the progress of my sign up so that I am not discouraged to use the app.	Given that I am a new user, when I sign up, I expect to see a progress bar.
Search Incident Reports	I would like to see previous incidents on a map so that I can explore the safety in different neighborhoods.	Given that I am a user, when I go on the Safe Map, I expect to see pins indicating a previously reported incident.
File incident report	I would like to file my own incident report so that I can report a crime and help other neighborhood members stay vigilant.	Given that I am a user, when I am on the Safe Map, I expect to be able to click a button to file an incident.
Start safe route	I would like to start a route planner so that I can navigate from point A to point B in the safest way possible according to my personal values.	Given that I am a user, when I am on the Safe Map, I expect to start a Safe Route by clicking a Safe Route button that is clearly visible.
View Safety Resources	I would like to have easily accessible safety resources so that I can call them if I need assistance.	Given that I am a user, when I am on the Safety Resources map, I expect to add a safety resource to my personal safety resources folder.
Access/View Communities	I would like to become a member of a community so that I can see community-logged incidents and view and chat with other members of my community.	Given that I am a user, when I navigate to “communities” in the main menu, I expect to see my personal communities or add a new one.
View Safety Category Weights	I would like to have an overview of my settings so that I can edit and set personal account details	Given that I am a user, when I go to settings, I expect to see an overview of settings options in a listing view.
Send Emergency Signal	I would like to have an S.O.S. button in the map section which I can click to send an emergency signal.	When I click on the S.O.S. red button, I expect to get a push notification with the choice of sending the emergency signal or cancelling the action.
Respond to Emergency Request	I would like to be able to respond to an emergency request to help a co-community member.	When I am a member of a community, I would like to get a pop up when a user within my community sends an emergency signal and have the option to respond or decline it.

4.5. Evaluate artifact

To evaluate the artifact, participants were asked to provide feedback about the artifact in accordance with the Technology Acceptance Model. According to this model, users are asked to assess perceived ease of use (PEU) and perceived usefulness (PU) for each of the system variables. This is accomplished through guiding the participants through a set of tasks in line with the use cases and user stories. An overview of the user feedback in line PEU and PU can be found in Table 4. The prototype was enhanced in line with the participants’ recommendations.

Table 4: Application feedback according to Technology Acceptance Model

System Variables	Perceived Ease of Use	Perceived Usefulness
Accounts	- Increase font size of sign-up button	

Category weights	- Change naming convention on slide bar ends	- Remove crime category weights from view - Add more subcategories to movement weights - Add a user explanation as an introduction
Safe routes and crime map	- Amend the menu wording - Change the color of the pins to red	
Incident reports	- Change the color of the pins to red - Add a filter for finding recent reports	- Add the option to upload picture in incident report - Add follow up button options after submitted report - Add a date filter to minimize exposure to previous crime reports
Communities	- Add filter for finding recent reports	- Add “report user” option - Add scan profile functionality for new profiles
Safety resources		- Add “tips and tricks” section for feeling safer - Start personal chat with community user
Emergency buttons		- Offline emergency signal option

5. Discussion

The design science research method used in this study aimed to address the explicated problem of participants experiencing challenges with regards to feeling safe and secure in the city. The study found that the most important requirement for the application as voiced by participants is the presence of an emergency button that can be quickly and easily accessed. This finding is supported by literature, as various studies touch upon the use of mobile services in harnessing safety and the importance of a silent signal to be sent out to police, which is one of the most echoed wishes [45]. This study provided more insights into this by revealing that ideally, the panic button should be accessible when the phone is locked which can be accomplished when the prototype is built into a working mobile application.

In terms of the destination of the signal, literature suggests the signal to be sent to community members or family and friends [46]. This research carefully evaluated the destination of the GPS emergency signal based on user interviews, and proposed something similar, where community members take on a central role as the first point of contact for emergencies in the community-based application. Interviewees stress the importance of having the community engaged in the mobile application prototype, because the success of the mobile application is dependent on community buy-in. This finding finds support in other studies, such as the study by [14] which observes that communities actively use online platforms to share information with co-members with a similar interest, with crime being one of those popular conversational topics.

Additionally, the study found that for the application to be successful, an important requirement is the implementation of a crime heat map from which users can view previously logged incident reports on a live map and start a safe route based on their personal wishes and needs. The study recommends a logging incident system as another unmissable feature. The incident reports are mapped for use of the safe route functionality, and additionally available in the crime heat map and communities’ maps. This is in line with literature which suggests that keeping citizens informed about crime incidents will provide them with knowledge to be more careful navigating through their neighborhoods [14].

As shown in Table 5, the prototype offers a combination of capabilities that are unique compared to the current availability of personal safety apps in South Africa, while keeping user friendly and easy to use according to participants. Looking at Table 5, this prototype offers functionalities that are rarely seen in other applications, including the possibility to add personal resources, plan a safe route based on previously filed crime reports, and the focus on community involvement and crowdsourcing. The latter is considered an important requirement by the participants in this study for the application to be successful. The possibility to engage with community members, share knowledge and call out community members during emergency is what separates this application from others in the field.

Table 5. Application prototype functionalities compared to existing personal safety apps in South Africa

Feature/Use Case	Research App	Namola	MySAPS	Life360	BullHorns	Safe Community App	MySOS	bSafe
Log in/sign up	✓	✓	✓	✓	✓	✓	✓	
Log Incident	✓		✓		✓	✓		
Safe Route	✓							

Personal Safety Resources	✓		✓					
Community Room	✓					✓		
Emergency Signal	✓	✓		✓	✓	✓	✓	✓
Private Armed Response	✓	✓			✓	✓	✓	
Response from community members	✓					✓		
Response from trusted friends/family	✓	✓		✓	✓	✓	✓	✓
Live GPS tracking and sharing	✓	✓		✓		✓	✓	✓
Ambulance Services		✓						
Live streaming of incident								✓

It is important to reflect on how the proposed mobile application prototype can lead to greater community resilience within a smart city. The study found that participants feel most resilient and confident about co-members of the community assisting in the case of an emergency as opposed to the police or friends, because there is a lack of trust in the police and friends, or family contacts could likely not be in the neighborhood. Provided there is a large community buy-in, the app would be used by many people and in effect, the likelihood of an active community member being in close vicinity of where an emergency signal is being sent is also high. The research further found that participants believe community engagement and social cohesion within the neighborhood have a positive effect on feelings of safety in the neighborhood because it shows a member can rely on the neighborhood and to help you when in need. This further helps build community resilience. The community chat room is necessary here to play a central role in facilitating communication and awareness between community members.

Previous research has shown that crowdsourcing, where information gathering through the internet is done by individuals, is often very successful because technologies that are based on crowdsourcing show to have an overwhelming participatory crowd [14,47,48]. Studies in Latin America and Brazil have shown that mobile applications using crowdsourcing related to crime prove successful in reducing the number of crimes in those areas [47]. The applications addressed here use a similar functionality where incidents are alerted to co-community members in the near vicinity [47]. This study’s proposed mobile application prototype makes use of the same crowd-sourcing methods for collecting crime-based data. Community members in the research have addressed their confidence in a large community buy in which could lead to the use of the mobile application prototype having a snowball effect for participation, for the purpose of feeling more safe and secure in the neighborhood with the help of the community, and therefore the study concludes that the smart mobile application will have a positive effect on community engagement.

6. Conclusion

This study provided insights into the design of a smart mobile application that can help citizens manage their fear of crime and improve their personal safety. Previous research has shown that issues relating to safety, security and fear of crime negatively impact urban life for citizens, and several studies suggest that improving the social engagement within communities might alleviate such issues [13,45]. To strive towards a city that is perceived safer by citizens, this research offered an alternative perspective that takes on a user-driven approach for developing a smart mobile application prototype according to the Design Science Research method with the aim of increasing feelings of safety and security. The study taps into Cape Town’s high mobile phone penetration rate and existing local government’s initiatives for building on smart pillars by proposing a mobile application prototype for citizen use. In doing this, the study places participants, who are in turn Cape Town citizens, at the front of the analysis and development process.

This study addressed the following research question: “How can a ‘smart’ community-based crime-focused mobile application prototype influence feelings of safety and security for Cape Town citizens?” Addressing the research question involves several aspects. Citizens must actively be involved in addressing smart-community solutions for the benefit of increasing the quality of life for citizens, which is one of the main objectives of the smart city [1,22]. This research accomplished this, giving citizens a central role in the problem description, requirement analysis and evaluation of the mobile app.

For the application to be successful, there is a need for community buy-in on a large scale, as the application is only argued to work when there is a large group of users to rely on for building a crime database and helping community members when in need. The application should be easily accessible, both in terms of quick access to the emergency signal as well as accessibility in terms of pricing, data, and connectivity, so it can be used by members from all types of communities in the City of Cape Town. However, most importantly, this research found that facilitating more safety and security for Cape Town citizens through the mobile application prototype is a first step in aiding citizens in being

more informed on the levels of crime in the neighborhood and share thoughts with different members related to safety. This is an essential step to building community resilience.

The research identified a few research limitations. Firstly, due to time and resource constraints, the study only included neighborhoods from the inner parts of Cape Town in its case study for research and analysis and excluded the wider areas of Cape Town which include the Klipfontein District, Helderberg, Northern Suburbs and the South Peninsula. Additionally, the study could have benefitted from a larger pool of interviewees if resources and time would have allowed it. Lastly, a limitation of the study can be identified relating to data connectivity and accessibility. Although mobile phone penetration is high across the continent and access to Internet is rapidly expanding, citizens are currently dealing with limited access to data because of the high costs as well as connectivity issues, especially in the outskirts of the city. This reduces the availability of the application to all citizens in the city and has a negative effect on large-scale community buy-in, one of the requirements of success for the application.

Emerging from the first limitation addressed in the previous subsection, future research could conduct large-scale interviews with citizens from all suburbs and neighborhoods in Cape Town, to get an understanding of their wishes and needs. In addition, future research on the topic could focus on performing interviews with all smart city stakeholders including local government and municipalities, to get an understanding of the smart city plans with regards to a safe and secure city. Results of these interviews should focus on alignment between citizen wishes and needs and municipal and local government plans to identify the gap between stakeholder interests. This will drive a mutual beneficial smart and safe city that is built on urban technologies and human experience. Future research should furthermore focus on linking logged incidents to law enforcement crime databases to analyze large scale crime data and tackle crime issues more efficiently going forward.

7. References

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