

Exploring the potential for Smart City technology for Women's Safety

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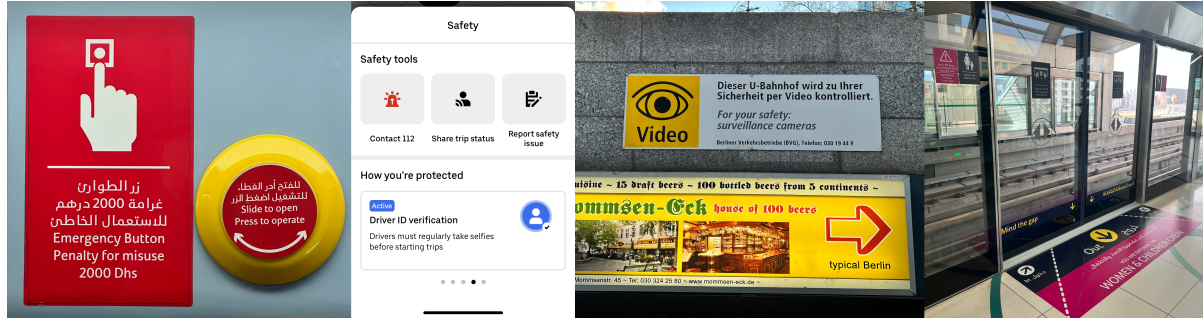


Fig. 1. Examples of urban technology for safety: alarm button in Dubai, screenshot of safety feature of Uber taxi, surveillance sign in the Berlin underground, and women-only underground cars in Dubai.

Safety for women in cities, in particular in mega-cities, is a major issue, given current approaches to city planning frequently neglect women's perspectives, resulting in cities where women and female-read people cannot move freely without being constantly worried about safety. Through a co-design approach, we explored the potential for Smart City technology to create urban environments that are safe for women. We ran a set of online co-design sessions, starting with three mixed and then eight city-specific sessions with female-identifying persons from Berlin, Melbourne and Cairo. Through these, requirements of women for smart city technology were explored and analysed in connection to the contexts of the respective cities. We found that in terms of practical solutions, ideas are always bound to the local context of the city, to routines of women's lifestyle, as well as to cultural specifics of the place. Nevertheless, general requirements for Smart City solutions across all cities similarly concern "Preventive measures", "Reactive measures", "Reporting support" and "Systematic changes".

CCS Concepts: • **Human-centered computing** → **HCI design and evaluation methods**.

Additional Key Words and Phrases: smart city, women's safety, feminist HCI, co-design

ACM Reference Format:

Margarita Osipova and Eva Hornecker. 2023. Exploring the potential for Smart City technology for Women's Safety. In *26th International Academic Mindtrek Conference (Mindtrek '23)*, October 3–6, 2023, Tampere, Finland. ACM, New York, NY, USA, 17 pages. <https://doi.org/10.1145/3616961.3616988>

1 INTRODUCTION

In many countries around the world, women's safety in cities is a big issue [35, 36]. This further increases gender inequality, as it restricts women from freely travelling around the city on their own [1], which limits their ability to take part in public life, work, and gain an education [26]. Women are generally more often exposed

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Mindtrek '23, October 3–6, 2023, Tampere, Finland

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ACM ISBN 979-8-4007-0874-9/23/10.

<https://doi.org/10.1145/3616961.3616988>

to unsolicited attention (including sexual) as well as harassment (physical and non-physical), while being less bodily-able to protect themselves [35]. Thus there is a need for measures for increasing safety.

Technology is widely used to increase safety, starting from passive surveillance to the level of reactive measures in case of attacks [1, 4, 8, 10, 18, 33, 34]. “Safety” is defined as “a state in which or a place where you are safe and not in danger or at risk” [14] and is used in academic literature in mainly in two ways: (1) the non-existence of danger or (2) having an ability to protect oneself or to be protected in a dangerous situation [18]. The latter is mostly relevant for solutions aimed on protecting in case of danger, while the broader meaning is more applicable to the urban context. Some of the existing solutions are present in most metropolises in various forms aiming to create save environments for women — women-only underground cars, alarm buttons, taxi safety features, and, of course, surveillance (albeit the goal of surveillance is usually wider, including reducing vandalism or theft), all presented in Figure 1. Nonetheless, most existing technological solutions fail to have an effect and do not change the situation, as they do not take actual requirements from women into account [19, 20].

A lot of the technologies used for solutions referenced earlier (GPS-tracking, alarm systems, surveillance, etc.) are also used as part of the data-driven system called “Smart City” [2, 7, 31]. Therefore, it is timely to explore the requirements for technological solutions to improve safety for women so as not to repeat previous mistakes of creating technologies that do not provide safety or do not properly function, and to avoid creating bad-solutions-legacy [25].

This agenda relates to Feminist HCI, not only topic-wise, but also approach-wise. It has been noted before that technology development and research, which does not include a gender perspective, is an issue within HCI. Rode [29] explains the consequences of not, or only shallowly engaging with gender, highlighting the importance of actively addressing gender issues in design. In our work, we turned to Modern Feminism through the lens of Feminist Standpoint Theory introduced by Harding [17], and the notion of “Situated Knowledges” by Haraway [16]. Both emphasize the importance of women’s knowledge about the world having a different perspective than what is considered common knowledge, extending it to the objective of exploring the knowledges of other marginalised groups or individuals, regardless their gender, in order to minimise bias in understanding of the world. This directly implies that design practices need to be more inclusive, so as to create space for women’s voices (or for other commonly ignored perspectives and standpoints) to be heard. Furthermore, Harding [17] discusses that gender is not a fixed entity, but concerns the self-identification of a person, and that gender is a social construct. These original theories are reflected in the work of Bardzell [3], which introduces ‘Feminist HCI qualities’ as a way to embed Feminism in design and research. These qualities will get introduced in the background section.

While the feminist perspective informs our research approach on Smart City for Women’s Safety, the notion of intersectionality [21] deepens understanding of the underlying problem. Intersectionality considers the marginalization of specific groups of people and explores connections between axes. Marginalization rarely is due solely to one characteristic, and moreover, these do not just add up on each other. For instance, a woman of colour would encounter not simply the sum of prejudices, and discrimination of women and of coloured people, but faces prejudices and problems specific to ‘dark-skinned women’, which result in a more severe situation. Kumar and Kurasala [22] discuss the implications for HCI, arguing that an intersectional lens can surface other facets of a problem and aspects influencing marginalization such as “nationality, domain of work, linguistic ability”, etc. For research on urban environments, a broader perspective is very important, given cities are diverse environments. Modern feminism furthermore addresses not only the marginalization of women, but takes a broader understanding of gender-related problems from an intersectional perspective, with the latest standpoint of feminism not being only about women, but about inclusiveness for other marginalized groups [3]. In this paper, the feminist lens was used for study planning and reporting with the considerations described above implied.

The goal of our research was to explore what needs and ideas women from mega-cities have (where the opportunity for smart city technology is highest) and how Smart City solutions might contribute to women's safety.

We organized a set of online co-design sessions, starting with three mixed and then eight city-specific research sessions with female-identifying persons from Berlin, Melbourne and Cairo. Our research question is phrased as: **What is common and what is different in the expectations from women from around the world for smart city technology supporting safety?** In our analysis, the following sub-questions allow to analyse and compare aspects of the results between the cities: Q1. What are the problems of women in different cities regarding safety? Q2. What causes “fear of crime” and what fears and discomforts do women experience? Q3. What do participants envision as a solution through Smart City technology? Q4. What aspects of the solution do participants pay attention to?

2 BACKGROUND — TECHNOLOGY FOR WOMEN'S SAFETY

The question of technology for safety starts with understanding the specifics of safety for women. Tandogan [32] found that the problem also lies in the fear of crime and not just in the issue itself, and that technology such as surveillance can be helpful [9]. However, some technologies created for this purpose do not always provide a feeling of safety and may even go unused. An example is the case of alarm buttons in New Dehli, explored by Karusala et. al. [19]. The city introduced alarm buttons on public transport, but they were rarely used. Karusala et. al. conducted interviews with women from the city and found that the button design did not take into consideration women's perspectives in important aspects, such as being sure that there is enough staff to react to the alarm, or that staying in contact with family is important to feel safe. This highlights the need for embedding women's actual values in the design of technology.

A way forward on this is conducting research and technology development so that it fulfills the Feminist HCI qualities introduced by Bardzell [3]. Embedding these qualities in a research process, allows embedding a feminist as well as intersectional perspective on the problem, broadening the perspective taken during research and analysis, and, therefore, helping to extend the results beyond the initial understanding of the dimensions of the issue in focus. These qualities are: Pluralism, Participation, Advocacy, Ecology, Embodiment and Self-disclosure [3]. “Pluralism” stands for creating designs that are human-centred rather than “universal”, thus promoting diversity and deep understanding of concepts, cultures, and needs of users. “Participation” encourages to include future users in ideation and prototyping, developing relationships with them throughout the whole design process. “Advocacy” aims to prevent the implementation of biased conceptions from developers into the end-product by including perspectives from underrepresented groups, or at least by acknowledging the underlying reasons and assumptions behind design decisions. “Ecology” prevents misunderstandings from how the product is affected by and itself affects the outside world. “Embodiment” encourages the acknowledgment of the user as a physical and emotional being, instead of a mental model. And, finally, the quality of “Self-disclosure” requests the product to be self-explanatory of what assumptions were made about the user in design process and implementation.

Karusala et. al. [19] noted that most of the issues with alarm buttons discovered in their study were due to a violation of feminist HCI qualities in the button's design: ensuring that there is enough staff to react to alarms – and users know about it – relates to the quality of Ecology, while Participation could have revealed, already early-on in the design process, the importance of staying in contact with family. Therefore, in our own research, we implemented the above-mentioned qualities in our research process and reflect on these in the discussion section.

Kaur et. al. [20] investigated the role of technological solutions for women's safety in the cities of India. Through a series of interviews, they explored the issues of navigating public spaces in India and the considerations around

technological solutions. Their key finding was that women expressed three aspects that need to be present in solutions: precautionary, reactive, and healing support measures [20].

Though many studies concerning women's safety explore the situation in India, statistics reveal that many other countries experience the same problem [35, 36]. Blom et. al. [4] conducted surveys and participatory design sessions with women from India and the US to design a mobile service that addresses the issue of fear. The resulting requirements highlight similar sources of fears regardless of country: darkness, potential incidents, and presence of unknown males being the most problematic contexts. In terms of the key requirements for a solution to reduce fear, the designed service should have comforting, preventive, or reactive use. Preventive and reactive use mean the same as in the research by Kaur et.al. [20], while comforting concerns measures for reducing fear without any particular threat being present. Nonetheless, a big difference between countries was discovered regarding what were considered to be the most problematic urban locations. For India, pedestrian areas, public transport, and private transport all had similar salience in mentions, while for the US, pedestrian areas were predominantly mentioned as being problematic. This suggests that requirements found for solutions for one place might not transfer to other places in the world. Further, requirements gathered by Kaur et al. [20] for India and by Blom et al. [4] for participants from India and the US are not identical, which may be due to the countries involved, but also to the fact that both studies focused on different technologies.

Most the studies investigating the topic of women's safety tend to focus on existing technologies or on creating new ones, based on existing technologies [10, 18, 33, 34]. Examples include wearables and mobile apps. However, other work has highlighted drawbacks for these technologies, such as battery life or solution reliability [4, 20].

The Smart City concept provides a potential alternative technological approach. It is described as a city that “takes advantage of communications and sensor capabilities sewn into the cities’ infrastructures” for improving the quality of life for citizens [11]. As dimensions of smartness in the city and related aspects of urban life, “smart mobility”, safety and security are listed [2, 23]. Currently several technological issues prevent this vision from becoming reality [7], which leads to most current research in the domain of Smart Cities for safety focusing on the technology itself [24, 28, 31]. Therefore, it is vital to explore the requirements regarding smart cities from the users’ perspective early-on, and to make the research inclusive and adhering to Feminist HCI qualities.

3 STUDY DESIGN

3.1 Co-Design for Urban Research

Co-Design is defined as “collective creativity” applied to the design process and can be considered as part of participatory design approaches [30] (with a focus on collective idea generation and creativity, whereas participatory design emphasizes user participation at all stages of system development and introduction). One of the important qualities of co-design is the ability to immerse participants in the context of a problem or question, and discuss and create from within this context, different to other methods where the problem is viewed from an outside perspective [12, 30]. This quality of co-design is vital for complex design problems and allows exploration of the requirements for designs that reflect feelings, experiences and ideas that emerge in direct context of the issue, surfacing the topics and dimensions that are less likely to be brought forward otherwise. This could be contributing to active use of co-design for urban research in the context of city layout and policy creation [5, 12, 13].

Co-Design provides an opportunity for a research process which has the feminist HCI qualities of Pluralism, by including diverse participants, of Participation, by inviting future users in the design process, of Ecology, through exploration of a real picture of the world by immersing participants in the context, and of Embodiment, by achieving an understanding of users on a deeper level, if carefully looking out for these aspects in the process of research. Advocacy and Self-Discloser are related more to the final product of the design, however, the design process with co-design employed, allows to pay explore these aspects in the process of designing already and

reflect on what values, concepts and perceptions made their way to the solutions, and how they are reflected in the solutions.

As a methodological layout for a co-design procedure, Cruickshank et al. [13] proposed a specific set of steps for urban-related projects: 1. Problem Statement, 2. Immersion and Empathy, 3. Synthesis, 4. Ideation, 5. Prototyping. This structure was used in our research with an Ice-Breaker added at the beginning and other steps being adapted to the research goal. This procedure was first trialled in a smaller pilot study [27], with online focus-groups ideating solutions. For the pilot study, session participants were from different cities, which provided us with first insights as well as experience regarding the methodic approach, but left questions open regarding the specificity of problems and solutions, which might differ between cities.

The procedure then was reworked and adapted, as well as optimized for the full study (to make better use of the time that people can work in a focused way in an online session). Furthermore, requirements for participation were defined more strictly. Lastly, each focus group session involved participants from the same city. Cities were selected to be very different, acknowledging that needs might differ, with the aim for higher pluralism (the first Feminist HCI quality).

3.2 Cities Focused on and Study Participants

The cities to invite women from were selected from the smart city index 2021 [15], considering which cities would be first to actually implement smart city technology and having more than 3 million inhabitants. This list was further reduced, to get to a manageable number, while being diverse in structures and cultures. This resulted in three cities: Berlin, Melbourne, and Cairo. The selection was partially led by the ability to find participants from these cities (via contacts over social networks) and the goal to investigate the effect of different cultural and urban contexts. Berlin is densely populated and has a strong public urban transportation system. Melbourne, as a newer city, is more wide-spread, but also has some public transportation. Finally, Cairo is mostly navigated by means of private car transportation, and gives us insights from a different culture and religious background, which might impact women's needs.

To ensure diversity of participants and with awareness of the sensitivity of the research topic, we used the following participant requirements: (1) participants should be women, or born as a female and presenting/being perceived as women,¹ (2) speak English, (3) be at least 18 years old, (4) from a city on the list or lived there for more than a year, (5) if they moved away that should not be more than 3 months ago, and (6) need or want to walk around on their own, or to whom safety is a concern. Participants were recruited through the university message boards, by asking contacts from academic networks who are from the respective cities to distribute our call for participation, and via other social circles and over social networks. Our recruitment explicitly was not restricted to native inhabitants, but aimed for a mix of backgrounds, including foreigners living in these cities, given it is known that these are often affected by double discrimination and likely to experience increased harassment (cf. the earlier discussion of intersectionality).

For the pilot, 10 participants were recruited through convenience sampling, with the only difference to the criteria of the main study being (4): having experience of living in a city with more than 1 million inhabitants. All identified as Female, age varied from 22 to 26. Eight participants were already in full employment and had completed academic degrees (Bachelor's or Master's), two were students. At the moment of the study, participants resided in different cities: Moscow (3), Munich (2), Weimar (1), Berlin (1), Prague (1), Tbilisi (1) and Marseille (1). Seven participants had previous experiences of living in another country and at the moment of study resided in a country different from their country of origin. Eight were not local to the cities they live in. All except for one

¹This criterion was phrased in this way to invite another perspective from a group that is affected by the same or related problems as a victim, to align with the feminist HCI quality of Pluralism.

were in relationships or married. Participants were randomly allocated into groups of 3 to 4 people. Each group participated in one research session giving the total number of three pilot sessions.

For the main study, 24 participants were recruited, of which 16 participated (not all could be aligned time-wise for a session). Eight focus groups with two participants each were conducted, three for Berlin, three for Cairo, and two for Melbourne. Out of 16 participants, 15 identified as Female, and one preferred not to say, all fitting the criteria of born as a female and presenting/being perceived as women. Age varied from 21 to 52 years, and all had experience living abroad. All Berlin participants were not originally from the city and only one out of six was originally from Germany. For Cairo, three out of six were not from the city and also not from Egypt, but moved there at least four years prior to the study, while the other three had lived most of their life in Cairo except for short internships abroad. In Melbourne, two participants were Australian, but only one local to the city. Two participants had moved to Melbourne from abroad and one within the country. All either completed or were in the process of completing an academic degree, and were either students (including PhD students), or in employment. The family status varied, with seven participants being single (those all lived in Berlin or Cairo), and the others being in long-term relationships or married. Only one participant (in Melbourne) had children. Lastly, all had lived in their cities for more than a year.

Participants were allocated into groups of two, so that both are from the same city. In the following, for quotes, we encode the participant number (16 in total) and the city, i. e. P01B, P07C, and P15M would mean participants from Berlin, Cairo, and Melbourne respectively. Quotes are all from the main study.

3.3 Materials

After recruitment, each participant received an info-sheet, consent form, and a demographics questionnaire. Further communication was done either through email or via messenger services for fast communication (i.e. scheduling sessions). Consent forms included information on the software used, what would be recorded, and how it will be used. For the demographics questionnaire, all potentially sensitive questions were non-mandatory and participants had the option to utilize their participant number instead of name. The actual database of participants was kept in our local university cloud.

The focus group sessions were carried out via video calls. For collaborative work, Miro digital board was used. For each group, a digital collaborative board was set up with a template created for this study. All participants had access to this during the study and were able to make changes. However, in some cases, due to technical issues, some participants could only join from their mobile, and then had issues writing on the board. This was mediated either by using a chat in the call or by the researcher as facilitator, writing on the board what they expressed they would want to put on there.

3.4 Procedure for the Sessions

The main study built on the pilot study. While in the pilot, partaking women in a session came from different cities, in the main study, participants of each co-design session were from the same city. Changes in procedure were small, such as updating the script. The resulting procedure consisted of seven steps, which can be seen in table 1. In the following, we describe the co-design process of the sessions step by step. In setting up this process, we aimed to take account of feminist HCI qualities.

1. Ice-Breaker: First, participants were asked to introduce themselves, to give their first names and pronouns, tell a bit about the cities they used to live in, and to share their favourite activity/hobby. The session facilitator also introduced herself. Then, participants were asked if they have any fears, concerns or open questions. Everyone was asked individually, to set the mode of the session. This is important to establish a balance of participants' engagement. It also was intended to make them feel safe, as any concerns could be resolved. Participants were further reminded they can ask questions and withdraw their consent at any point.

Table 1. Main study procedure

Num.	Step	Agenda of the step	Participants' involvement
1	Ice-Breaker	Participants introduce themselves	Actively involved
2	Goal of study	Goal of study was presented	Passive, open for questions
3	Problem definition	Sharing of problematic situations and issues	Actively involved
4	Scenario definition	One issue selected and scenario created	Actively involved
5	Smart City Introduction	Explain Smart City concept and technologies	Passive, open for questions
6	Solution ideation	Brainstorming Smart City solutions for scenario	Actively involved
7	Solution concept sketch	Presenting solution ideas in one concept	Actively involved

2. Goal of Study: Next, the facilitator presented the overall goal: “to come up with a solution for making cities feel safer for women through Smart City Technology”. This was to give participants a clear goal, while fostering engagement and an understanding that every process phase contributes to this goal. The phrasing was to avoid leading in any particular direction, while giving space for different interpretations of what “safety” and “feeling safe” could mean.

3. Problem Definition: For brainstorming, participants had access to a Miro board (a digital collaborative board). They received prompts on fears for their safety, on things they experienced, and were asked to describe the situation, place, and discomfort or fear. The core question was: “What are situations when you felt unsafe or went through a real danger?” This phrasing allowed for bringing discomfort to the table, which is vital to understand the non-factual side of issues. Participants had 5 minutes to write notes on their own, then every note was presented verbally to create a shared knowledge space and compassionate relationship between participants.

4. Scenario Definition: Now, a concrete context was chosen. Participants were asked to select an issue from the brainstorming they are concerned about the most and want to try to resolve. Then, the group created a scenario/story for which a solution can be developed. They were allowed to add pictures, text, videos to the Miro board - any related content that helped to immerse themselves in the situation. Finally, they were asked to describe the scenario verbally. The facilitator did not influence problem selection and scenario construction in any way.

5. Smart City Introduction: Considering participants' diverse backgrounds, the ‘smart city’ concept was introduced as a separate step. It was presented as an “urban environment utilising technology and data gathered through it, for proving better quality of life for citizens”. The definition was not aimed to be academic or precise but rather understandable to anyone. Then, examples of application areas (healthcare, city management, safety...) were introduced and some common technological solutions (IoT, with examples of smart home appliances, Artificial Intelligence, etc). To encourage creativity and freedom of ideas, participants were reminded that a lot of smart city technology is not yet developed to the required level, and they are free to work on solution ideas, regardless of the current state of technology or their understanding of technical implementations.

6. Solution Ideation: Participants were reminded of the scenario chosen to design a solution for, and were asked to collaboratively brainstorm ideas, putting them on the Miro board, regardless of feasibility. Participants were given 20 minutes to discuss and organise ideas

7: Solution Concept Sketch: The group were asked to create a complete concept or solution, based on their ideas, in a way that “it can be brought to a local city council as a proposal for implementation”. A core aspect of this task was to have participants critically reflect whether they want something to be implemented in their city, and also to ensure a sense of achievement regarding the goal.

This procedure ensures for everyone to be heard, and for sensitive and emotional topics to be discussed (all steps aim to contribute to the feminist HCI qualities of Pluralism, Embodiment and Participation), creates a space where problems are discussed in a real context (with step 4. contributing to Ecology), and gives space for critical reflection, preventing biased ideas from being implemented (step 7. contributing to Advocacy).

The sessions took between 40 min and 1:40 h. All ten studies ran online. However, two sessions (both for Cairo) were audio-only due to technical difficulties, as some participants could not join from a computer and instead used their phones. As active participation in the call and on the Miro board was very difficult and taxing for participants, the brainstorming then was carried out purely verbally and the researcher wrote their ideas on the board. Nevertheless, the board was visible to participants all the way through, so they could verify whether the text added to the board reflected their contributions adequately. All studies were video recorded and transcribed. Outcomes of the Co-Design procedure were saved on the Miro board.

3.5 Analysis

For our analysis, we focused on the transcripts of the video recordings. The contents of the Miro board were occasionally used to retrieve context while coding, e.g., if there were uncertainties about statements' meaning. Since all information on the board was repeated verbally in more detail and discussed by participants, the transcript provided more detailed insights. Analysis and coding focused on step 3 (problem definition), step 6 (solution ideation), and step 7 (solution concept sketch).

Coding followed a thematic analysis approach [6] via Open Coding using MAXQDA software. Codes were derived from transcripts and phrased to either describe the story told or to highlight interesting parts. For example, for the following statement from P03B: *"People around were just watching, so that there were people around. They were just looking at this whole thing"*, two codes were assigned: 'people are ignorant to the problem happening' and 'other people are there'. In a second step, codes were merged if the same thing was described twice in different words. After coding was completed, codes were sorted into 'buckets' with respect to research questions.

A first bucket *"Problems"* contains all codes related to problems. However, while reorganising codes it was discovered that problems and fears were discussed interchangeably. Participants spoke of things that did happen to them and of things they were scared might happen to them (see the concept of "fear of crime" [32]). The second bucket is *"Context"*, which contains all follow-up details such as time of day or why the person got into the situation, for example, *"walking the dog"* or *"living nearby"*. The bucket *"Safety Strategies"* included what they do to avoid, solve, react, or how to protect themselves from a potential danger. Examples include *"consider what to wear"* or *"choosing a safe path with people"*. The last bucket is *"Solutions"*, which contains all ideas about envisioned solutions and related aspects.

Finally, codes within buckets were inductively grouped into overarching themes reflecting the underlying concepts for *"Problems"*, *"Safety strategies"*, and *"Solutions"* (like *"spatial separation"*), and reflecting what they describe for *"Context"* (*"places"*, *"emotions"*). For these themes, the frequencies of mentions within cities were also analysed. As the last step of analysis, the connections between the codes within cities were mapped and categories of solutions were built, based on the solution idea codes.

4 FINDINGS

In analysis, we constructed relations between the themes contributing to requirements and patterns on requirements. Next, we introduce and compare the most frequent codes for the three cities, and the overarching themes and their relations.

4.1 Problems Space and Context

Table 2 shows the most frequently mentioned problems for each city. The most mentioned overarching themes for all three cities were “*unsolicited attention*” (top 1 for Berlin and Melbourne, top 3 for Cairo), “*cannot protect oneself from danger*” (on the 2nd place for all) and “*unstopped harassment*” (top 1 for Cairo, top 3 for Berlin and Melbourne).

As problematic places, “*closed spaces*” were mentioned as well as different pedestrian zones, such as “*streets*” or “*parks*”. Other overlapping context codes concerning “*darkness*” and “*at night*” were connected to other issues mentioned for the places. For all cities, different means of transport were mentioned, but neither of “*public transport*”, “*cars*”, or “*taxi*” was noted in all three.

In the pilot sessions, similar trends were there, with “*Streets*” being the most mentioned context of problems, and “*public transport*” coming second place. The source of problems were “*men*” or a “*group of unknown people*”. The most frequent themes featuring the underlying issues and fears were that “*somebody does something to her*”, “*being unable to protect oneself or to be protected*”, “*unsolicited attention*”, and “*emotional discomfort*”.

From table 2 it can be noticed that similar issues occurred in different contexts. For instance, participant P01B from Berlin described uncomfortable looks: “*You sit alone on the tube. And there’s just some random guy coming sitting next to you. And he’s always looking at you*”. Participant P07C from Cairo highlighted a driving alone experience: “*It’s when you’re driving and any truck (is) with you on the road, all the workers on the-this truck, keep looking at you and extremely extremely uncomfortable way*”.

Another example of local differences was in the ways and places, that ‘weird’ (meaning acting strange or being under the influence) people approached women. P05B from Berlin told: “*when the doors closed, some men, he set next to me and then he started talking to me and like flirting with me and everything and that was really scary because I wasn’t interested*”, while P15M from Melbourne told a story about “*walking back from the train station to home, and my route goes alongside quite a big park, and it was the middle of the day as well. And this dude just comes up to me and starts chatting in that way, that happens. And he’s like: oh, you know, who are you? Where? Are you going? What’s your name?*”.

Lastly, a couple of themes appeared only in one city. These tended to be more extreme and were bound to the local context. An example of such was noted by P09C from Cairo that “*dressing up, or like, you look like you’re going somewhere, just immediately you have like cars slowing down, cat calling you, people calling you, people getting in your ways. Specifically men, just tell you ‘where you going’ and (ask for) your number. It has like this happens, like everywhere, if you’re dressed up and you’re just walking, once you’re outside of your car, it’s always like a very bad walk*”.

4.2 Selected Scenarios

Although participants in each session could choose their own problem and scenario to work on, all groups who came from the same city chose a similar context — despite having various problems mentioned in the initial discussion of issues. For the two sessions with participants from Melbourne, the chosen scenarios concerned *coming home alone at night*, all three groups from Cairo decided to focus on *street harassment*, and the three Berlin-based groups selected the scenario of *unsolicited attention by strangers in and around the underground stations*. Moreover, for some issues, the exact locations in the cities were mentioned, similar to the ones introduced in the problem discussion step. In the pilot, this also occurred — the same situations were selected by all three groups, despite women coming from different cities. All groups chose cases related to an unknown man or a group of men, when it is dark.

Table 2. The most mentioned problems and context codes for the cities

Berlin	Cairo	Melbourne
Unsolicited attention		
Stared at on public transport Beggars, people under influence, homeless or strangers acting weird on underground or near stations “Weird” people approach and talk to you in the underground Being followed by “weird” people	Stared at on road and streets Asking for help triggers unwanted attention Dressing up considered a permission to approach Being followed home	Fear of being watched People under influence, strangers acting weird on streets, near cars or around private residence “Weird” people start talking on the streets Being followed home
Cannot protect oneself		
Fear of robbery Discomfort of travelling drunk (line changes at night with waiting) Lack of connectivity to contact someone for help from underground Being in the way of bicyclists Not knowing local culture in city Open racism Unsure what self-defense is legal Not knowing what to do while being in dangerous situation alone or in shock	Fear of harassment and robbery Driving alone Lack of connection to contact someone on highways Fear of walking streets alone Not knowing local ways and identified as outsider, thus a potential victim Feeling ashamed to report issue Self-defense is not fully legal Fear of asking for help in unknown situations not to make it worse	Fear of robbery Drinking outside (drinks can get spiked) Fear of getting taxis in taxi ranks Unsafe streets (walking alone at night) Fear of speaking up, not to trigger more problems Fear of bad reaction to “no” Not knowing how to react while in shock
Unstopped harassment		
Uncomfortable touching in private setting or on transport Fear of physical damage as result of harassment on bike or after being followed Homeless people throwing things Being shouted at Verbal and physical aggression towards immigrants Catcalling	Uncomfortable touching on streets Fear of physical damage as result of harassment for robbery or assault Harassment from police Others shouting Verbal harassment because of appearance or clothes Dirty words, catcalling, bad names	Uncomfortable touching on streets and on transport Fear of physical assault Unknown men throwing things Others shouting Verbal harassment because of appearance or clothes Catcalling, bad names
Other themes		
No protection from law and authorities (not speaking the language or police ignorance to reported issue) Others being ignorant to problem and not helping Inability to avoid problem (on underground)	Laws that support men and unreliable police not taking reports Cultural expectations make women legitimate targets Exit blocked or taxi doors locked	Not having enough data to file report Surrounding (eg. loud music) won’t allow others to notice issue Exit blocked and not able to leave unnoticed or taxi doors locked

4.3 Existing Safety Strategies

Many participants talked about “Safety strategies” that they use to avoid or mitigate the issues, despite not being asked directly about this. The most mentioned strategies across all cities were “awareness”, “human contact and witnesses”, and “spatially avoiding the danger”. What was most mentioned differed across the cities (for Berlin: “Spatially avoiding the danger”, for Cairo: “Awareness”, for Melbourne: both “Awareness” and having “Human contact and witnesses”). Melbourne participants emphasized sharing location, or staying in touch with friends and family via their phone. The Cairo sessions also brought these strategies up, but also an additional one of needing a man to accompany a woman on a walk. Needing a man as guarantee for safety was mentioned only for Cairo, whereas for Melbourne, company usually meant “friends” regardless of gender.

For Berlin, “Verbal reaction to protect” was a common strategy that did not come up for the other cities as much. Only in one instance for Berlin, “governmental help” was spoken about in the context of the media raising awareness about the problem. In contrast, Cairo participants mentioned “governmental help” the most often. They often said the situation “is getting better” and that “they are trying to set the laws to be on the women’s side” (P08C). Yet they also mentioned that this does not actually improve the situation, also, issues regarding current sexist laws were mentioned. For Melbourne, “Spatially avoiding the danger” was another common strategy.

4.4 From preventive to reactive - 4 types of solutions

Both in the main sessions and the pilot sessions, groups always suggested three types of solutions. In each city, “preventive measures”, “reactive measures”, and “systematic changes” were proposed. However, in the city-specific sessions another type appeared that was not proposed in the pilot sessions: “Reporting support”. Ideas include technology-mediated as well as human-mediated solutions, and include ways how the urban or social layout can be changed to support the required measures.

The range of technologies proposed in these solutions had a lot of overlaps between cities: mobile phones and mobile apps, video surveillance, various automatic actuators, etc. Several technologies were proposed only once and for very specific purposes, such as a walking robot buddy. However, it was never only technology in any solution concept proposed and non-technology related solutions were mentioned almost just as much.

4.4.1 Preventive Measures. All solution ideas that aim to avoid or reduce the chance of the issue happening were considered “preventive measures”. The themes in this category include “travelling with trusted person”, “automatic detection systems”, “avoiding bad places”, “people monitoring”, “being looked after”, and “reducing isolation through staying in contact”. These themes involved mobile phones, features that provide a connection to others, and infrastructure improvements like “better wifi in the underground” (Berlin), maps of safe routes or lists of known local dangers/harassers (Cairo), apps and buttons to connect with others to walk together, tracking location for detecting potential anomalies, and video surveillance for “everything being recorded, so women feel safe” (P07C). Though this category included technological ideas, most featured a connection to other people experiencing similar issues, to community generated knowledge about local safe and unsafe areas, or staying in contact with friends and family. Futuristic or smart city technology was barely touched upon in this category, and most of the ideas featured improvements to current technologies.

4.4.2 Reactive measures. The second category of solutions groups ideas related to identifying a problem and reacting to it. The biggest number of themes were present in this category: “being looked after”, “reducing isolation”, “automatic detection”, “self-reporting in-situ”, “speaking same language”, “confirmation of a problem happening”, “immediate solutions”, “spatial separation”, “people coming to help”, and “catching the harasser”.

Also, lots of technology were proposed and new non-existent ones came up the most. Various means of auto-detection were proposed, from voice, video or location analysis, to detecting emotion from a mix of parameters, or for the urban environment itself to identify problems such as a “person coming along who needs more lighting”

(P15M). Self-reporting technology included voice-based input and tapping, specifically buttons on the phone, on streets or transport. For buttons, it was important for their use to go unnoticed by harassers. However, both for self-reporting and automatic reporting, as a requirement for taking action, an explicit confirmation of the issue by the victim was mentioned, such as *“if they [taxi driver] have changed a route, you can get a phone call”* (P13M) by either trusted friends or by police. Also, when solutions involved action to be taken, the need for people to come was mentioned, be that police, friend, family or *“trusted people”*. Here, the ability to notify these people in case of issues was emphasized.

There were three ideas for immediate actions that can be done by technology alone - to create a safe space around the victim (sort of a shell) that can be carried around, a self-driving car to come rescue a victim, and an electric buzzer to automatically stop a harasser that breaches private space (all for Cairo). Lastly, solutions for catching a harasser featured cameras and remote vehicle control, but in this case for *“the guy [harasser] to get punished”* (P07C). Despite this category being the most technologically advanced, technology was mostly trusted for auto-detection or informing people about the problem – but only if verified by the victim (or if the victim does not confirm they are fine, to still send help, to eliminate false alarms). Active solutions mentioned bringing the person to the safe space. All intervening action ended with people or police arriving.

4.4.3 Support for Reporting. A new category from city-specific sessions describes measures that can be taken to support the victim in the process of reporting an incident. One of the participants from Berlin said that *“video could call help with that [recording], because sometimes it’s self-explanatory and you don’t need to describe a person who hurt you”* (P02B). Main themes included *“catching the harasser”*, and one specific to Berlin was *“speaking same language”* (i.e. German). For catching the harasser, there were several steps highlighted in the ideas from participants: auto-saving video or audio recording of the issue happening, sending them directly to the police from the moment of automatic detection or self-reporting, and then turning it into a police report, only asking for the person affected to confirm that the report is correct. Language issues featured in both reactive measures and reporting support only for Berlin, where police do not (or do not want to) speak English. Technology for immediate translation via phone or embedded systems was proposed.

4.4.4 Systematic Changes. The last category includes all ideas that propose changes in the city or in society, that cannot be done overnight and require an actual change of the system. Featured themes were *“Changes in the environment to make it safer”*, *“changing perception of people and awareness”*, *“spending less time”*, and *“avoiding bad places”*, as well as *“spatial separation”*, *“reducing isolation”*, and *“speaking the same language”*. However, the solutions in this group mostly were not about technology at all. Participants either stressed the need for the environment or for people to change. Changes in environment included city planning adaptations, improving dangerous areas, introducing more people of authority to those areas, new standards for public transport that separate potential victims from potential dangers, such as underground carriages that people can walk through so they are not stuck with bad company, or having more space between driver and passenger in taxis.

Changing society requires making people of authority more aware and educated about the problem, and de-normalizing harassment altogether. Technology as a help for systematic change was mentioned in the Smart Applications the most in this category. The Smart City is data-driven by design and tech solutions truly reflected that: the idea of upgraded public transport was introduced for Berlin and for taxis in Melbourne, and changed urban environment with sensors was discussed in Cairo. Things such as data gathering sensors integrated and connected to the hub were mentioned a lot, where the transport will in a smart way detect issues and anomalies and then transfer data and send the alarm to police. All these ideas were presented as something that should be implemented on the whole city scale to be working to the full potential.

4.5 Local specifics of the solutions

Within the big categories, that most themes were present for all cities, each presented itself in a different way in the solutions proposed for cities and women raised different hesitations.

4.5.1 Potential future technologies per city. In the sessions for Berlin, where a lot of people are internationals, ideas were often inspired from experiences of life in other countries, such as women's underground carriages, that are common in Muslim countries. Also, solutions helping with the local language were discussed only for Berlin, as well as systematic changes helping homeless and addicts to integrate back into society so as to make "*weird people less weird*", as mentioned by participant P01B. In Cairo, ideas related to catching the harasser were mentioned the most, and were reflected in ideas of all types, as well as the technological solution of self-driving cars (for not walking alone through unsafe areas). Cairo also was the only city, where solutions were suggested that involve wearable for protecting personal spaces. In Melbourne, surprisingly ideas for help by peers were not very popular, but the idea of a walking robot to accompany women through unsafe areas was proposed. The idea to require confirmation of a problem before triggering action was Melbourne-specific as well. Finally, only Melbourne participants suggested educating the authorities on the issue of safety through immersive virtual reality environments, to make them experience how it feels to be a woman in the city, so that this experience would inform decisions.

Other ideas and considerations overlapped between cities. Solutions with walking buddies feature the same technology for Berlin and Cairo - apps and buttons to alarm the buddy community, though in Berlin there was no specification of the community to be a community of "*known*" or "*trusted*" people, as it was for Cairo. Also, the ideas of spatial separation were more prominent for these two cities. Auto-detection was present in all cities, but was most frequent in the solutions for Melbourne. However, Melbourne participants aimed to have little to no surveillance. In Berlin, the issue of sharing data and being constantly observed was raised as well. But here, the idea of consenting to being recorded was proposed as part of the solution, by going into the observed area, searching for safety, and by choosing that place to consent implicitly to being recorded. Also, for Berlin, surveillance was suggested as a solution for public transport, while for Cairo this was for the streets. Safe spaces were mentioned for all cities, but in Berlin they were proposed as part of the public transport system and for every station to have one, for Cairo it was proposed for dangerous area, and for Melbourne they were proposed for the purpose of safe drop off spots from the Taxi.

Lastly, women in all sessions critically reflected on the solutions proposed during the ideation phase and raised their concerns, such as data privacy discussed above. Women from Berlin were hesitant on whether their proposed technology would not give the result fast enough after using it to signal a problem (for example, while moving between underground stations), and the victim would not know what to do until then. In the Cairo sessions, some ideas were excluded after discussion from the final concept to be presented at the end of the session as "too unrealistic for the government to agree", or because women did not trust the government in general, especially with surveillance, although they had discussed it a lot as a tool to catch the harassers. Another question discussed was whether their ideas would help to catch the harasser or scare them away only after they did what they did. The Melbourne participants did not want to encourage increased surveillance and wanted control over the auto-alarms to confirm the issue. The hesitation raised in all cities was about solutions backfiring or creating "*unintended consequences*", such as weird people waiting near those safe spaces for victims, or the technology being used too often by accident, making real issues go unnoticed or ignored (often referred to as the 'cry-wolf' effect).

5 DISCUSSION

In this paper, we discussed the four types of solutions that women mentioned as expectations for Smart City technologies: (1) "*Preventive measures*", (2) "*Reactive measures*", (3) "*Reporting support*" and (4) "*Systematic change*".

For each city, all four types were mentioned within the ideation process. This phenomenon was observed in the pilot for the types (1), (2) and (4) [27]. The first two types have already been listed in the resulting requirements in the studies by Kaur et al. and Blom et al. [4, 20] (our study thus confirms their relevance). The absence of the other two types might be explained by other studies focusing either on existing or on realistic technologies, while in our study participants were instructed not to limit their imagination.

Another reason to why four types were found, instead of just two, could be that participants were not asked to provide technology-only ideas. All four types involve a mix of technology-related and -unrelated ideas. This is also reflected in how the technologies were utilised: for preventive measures, technology served as mediator for human connections or for detecting safe areas of the cities via community-made maps; for reactive measures, the biggest number of tech ideas was proposed, but these featured issue detection, to solve the issue people were contacted; for reporting support, the whole task was delegated to technology; and for systematic change, it was either not related to technology at all or, on the opposite, proposed canonic data-driven Smart City application ideas. This finding gives a better understanding of what technology, and for what purpose would be trusted by people and sensible to use.

A topic relevant to our findings is ‘feeling safe’ in a city. The four types of solutions cover the phases of danger that women experience and lead to the possibility to reduce the “*fear of crime*” [32]. Tandogan [32] describes that fear appears even before actually experiencing on issue. Thus, only solutions that address the problem on every level can successfully solve it, and create urban environments which are safe and comfortable for all genders.

The findings show that local specifics were very different between the cities. This can be explained by the city context, urban layout, and local lifestyle. Berlin vastly relies on the underground in terms of transportation, which is thus the main discussed location for problems, leading to solutions focusing on it. Melbourne and Cairo are more car-based cities, thus both problems as well as solutions featured cars. Yet, culture itself has an even bigger influence on the situation in the cities, for example, in Egypt the basis for harassment was sometimes defined by expectations regarding women’s behaviour and looks, influenced by religious (and/or cultural) beliefs. Demographics also play a role, as in Berlin, where the population is very international, the issue of not speaking German language was raised a lot, while for the other two cities, this was not a problem. Also, having international experience provided more ideas for solutions, as many of the ideas in the Berlin groups were inspired by travelling experiences, such as alarm buttons. Another important factor of the context is the relations between citizens and the government, resulting in different considerations in regard to the solutions design, and how much authority over data should be given to the police.

These considerations, though not being directly introduced by participants, would be important to explore for designing Smart Cities in the future. As we showed here, the local context is vital to be taken into consideration and thoroughly exploring it beforehand should be a requirement for any Smart City concept to be implemented. The most problematic issues of the places were named the most often and then were selected by participants as the scenarios to work on. Later, safety strategies found their reflection in the solution ideas, through having at the core similar concepts within one city. For example, “*spatial separation*” for Berlin is both a safety strategy and solution. The context influenced both problems and safety strategies, thus also influencing the solution ideas the most.

Although the feasibility of proposed solutions is beyond the scope of our paper, it is important to acknowledge resulting implications for Smart City solutions based on both technology-related and -unrelated ideas. Technological ideas of all four types imply the use of underlying concepts discussed in section 4.4, rather than using technology blindly. Therefore, the feasibility of any potential solution should be assessed first through the lens of feasibility regarding the underlying requirement, and combat the underlying fear or issue, rather than to solely assess technical feasibility. Moreover, technology constantly evolves, and thus technological options expand. Therefore, taking technological progress into account, feasibility should be evaluated based on whether the planned solution to be developed fits the goal, and whether by the point of implementation, it is likely that

the technological market will be good enough for it. Thus, this question is for further exploration by other researchers.

Non-technical ideas require the same approach. However, the overall feasibility of implementing these solutions highly depends on support from local governments. Solutions of all four types imply changes within society, and these changes cannot happen fast. City layout, harassment preventing policies, changes within the justice system, etc., are all long-term goals. Nevertheless, they are still entwined with the Smart City concept, mainly on the basis of creating the environment, in which Smart City solutions will function. Therefore, the core implication of non-technological Smart City solution ideas would be to always ensure that the environment indeed supports the Smart City instead of contributing to the problem. This additionally relates to the Feminist HCI quality of Ecology, ensuring that a solution should never be discussed outside of its real-world context.

Although this research was done for three different cities with completely different cultures, history, urban layout and local context, it should be acknowledged that new requirements might be uncovered when investigating other cities. Thus, we cannot yet be fully sure whether our findings can be generalised beyond the four universal requirements. In addition, we had encouraged women to ideate ideal solutions without considering feasibility, thus, in practice there would be the necessity of exploring technologies with limitations and safety issues. For this, more research on local context will be needed, as well as explorations of how the data gathered will be treated by authorities.

Finally, the co-design procedure that we designed and employed can be used as a basis for further research and by other researchers. The results show that feminist qualities of Pluralism, Participation and Embodiment embedded in our co-design procedure provided a deep understanding of the problems as well as requirements to solutions to the level of values, emotions and ethical considerations, that participants implied to their solution ideas. The latter also proves that the quality of Advocacy was fulfilled as the solutions were grounded in the values that women stood for (and which also varied between the cities reflecting locally important aspects). Quality of Ecology vastly contributed to both, as ideas created in the context of a problem included the local background and allowed to create solutions that are fitting particular place, and, therefore, reflected the real situation and limitations, that should be considered. Lastly, the quality of Self-Disclosure, despite being more applicable to the final product of the design, was also paved to be present in the solutions coming from such design process. But we argue that the analysis of how the ideas came to life and who proposed them in combination with the discourses around them during the ideation, can provide enough explanation to the initial assumptions and values that are at the core of the idea. Therefore, we conclude with claiming that initial design of the study, if made feminist, can afford for the depth of exploration and inclusiveness, giving the result that go beyond what non-feminist studies can provide and prevent from having understanding of requirements and solution ideas, that show only a fractal part of the real picture. Therefore, this approach, if refined, can help render site-specific knowledge about women's safety in cities and site-specific solutions.

6 CONCLUSION

In this paper, we explored similarities and differences in the expectations from women and read-as-women people from around the world for smart city technology supporting safety. We ran co-design sessions with women from Berlin, Cairo, and Melbourne, and earlier ran similar sessions with women from around the world in a pilot. The aspects of problems and contexts were explored and compared between the cities, as well as how they influence solution ideas for smart city technologies. The main discovery is that Smart City solutions that could help to reduce the fear of crime and make the situation of women's safety better should include four types of solutions: (1) *“Preventive measures”*, (2) *“Reactive measures”*, (3) *“Reporting support”* and (4) *“Systematic change”*. However, technology was not enough for any type of solution, and the level of how much was delegated to technology varied between types. Lastly, despite proposing the four types of solution that should be present in Smart Cities

for safety, we discovered the requirement to always take local context and lifestyle into account, as it defined the ways how and for what the technology can be used for every specific place, as well as what problematic issues the technological choices can imply.

ACKNOWLEDGMENTS

We would like to thank our participants without whom this research would have been impossible, our fellow colleagues Britta Schulte and Rosa van Koningsbruggen for advising on the approach and reviewing the manuscript, and anonymous reviewers for their feedback and for bringing in new perspective on how our research contributes to the HCI community.

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