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Abstract

The cultural shift in World Wide Web technologies known as Web 2.0 has facilitated a rise in user-generated content and participatory culture online. Notably, crowdsourcing has emerged as an innovative method of collaborative data collection. Online crowdsourcing has revolutionised contemporary academic research by enabling the general public to pool their skills and knowledge together in projects worldwide. This research project aims to test the boundaries of crowdsourcing, as a means of knowledge production and, more specifically, geospatial data production in the digital age to address the issue of safety in cities. In particular, this project investigates how crowdsourcing local knowledge, opinions, and experiences can enhance pedestrian safety and identify safer routes for navigating urban areas. This research was carried out through the creation of a digital artefact titled 'SafeScape', a web-based interactive crowdsourcing map of the broader Cork City area, developed using Google Maps API, HTML, CSS, JavaScript, and a NoSQL database. SafeScape enables participants to identify and place markers on locations they consider safe or unsafe and provide contextual reasoning through an additional survey element. In turn, this study explores the factors that contribute to feelings of safety in urban areas, such as the time of day, location, and the built characteristics of the environment. The result of this crowdsourcing tool is a unique mapping resource integrated with safety considerations, hoping to assist vulnerable groups and those unfamiliar with the Cork City area with safer pedestrian navigation by highlighting potentially unsafe areas.

Declaration of Originality

In signing this declaration, you are conforming, in writing, that the submitted work is entirely your own original work, except where clearly attributed otherwise, and that it has not been submitted partly or wholly for any other educational award. I hereby declare that:

• this is all my own work, unless clearly indicated otherwise, with full and proper accreditation;

• with respect to my own work: none of it has been submitted at any educational institution contributing in any way to an educational award;

• with respect to another's work: all text, diagrams, code, or ideas, whether verbatim, paraphrased or otherwise modified or adapted, have been duly attributed to the source in a scholarly manner, whether from books, papers, lecture notes or any other student's work, whether published or unpublished, electronically or in print.

Signed:

Date: 04/02/2025

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Link to project website: www.safescapecorkcity.com

Introduction

In recent years, the concept of urban safety has extended beyond traditional crime statistics and official policing data. According to the Garda Attitudes Survey 2023 (Copeland and Walker, 2024), the Irish public tend to feel significantly safer in rural areas than urban areas. While recorded crime incidents in Ireland have decreased in recent years (Central Statistics Office, 2024), these feelings of unsafety held by the public highlight an anticipation by Irish citizens of 'anti-social behaviour' and crime in urban areas. From this research, it can be seen that safety perceptions can vary due to demographic reasons such as age and gender identity, as well as factors such as the time of day. These unique insights into public perceptions and experiences are crucial in developing safer cities. Crowdsourcing offers a promising avenue into this subjective data. International projects such as Safetipin and YourGround facilitate this, however there is no equivalent application made for pedestrians in the Cork City area or other urban areas in Ireland. This research explores how participatory methods of data collection such as crowdsourcing can be used to enhance pedestrian safety and aid in navigating safer routes. By gathering local sentiments and experiences, crowdsourcing maps can highlight potentially dangerous locations and give insight into the complex safety dynamics of an urban area. Integrating this information into a map in this way can help pedestrians plan routes based on safety, as opposed to just convenience.

The proposed digital artefact, Safe Scape, is a live crowdsourcing map of the broader Cork City area, enabling users to give in-depth insights into locations that they feel are safe or unsafe. This approach not only reveals key influences on perceived safety in urban areas, but also creates a dynamic, community-driven resource for safer navigation. The design of the artefact allows nuanced and layered analysis combining geospatial, textual, and sentimental elements. In turn, the design of this digital artefact sheds light on some of the factors that contribute to how safe an area is perceived to be such as the time of day and characteristics of the built environment. By recognising factors that contribute towards feelings of unease, such as a lack of street lighting or inadequate security presence, Safe Scape provides the locals of Cork City a space to voice their opinions and experiences navigating the area, which can be used for future urban planning to enhance local experiences. In this study, a substantial literature review of similar research was conducted to investigate how an element of safety has been integrated into current mapping tools, as well as the complex components that

influence feelings of safety. This review also discussed the social implications of crowdsourcing safety perceptions. Following the literature review, it will be demonstrated how this research has inspired and has been reflected in the design of the proposed digital artefact. Finally, this study will also share the data collected thus far, giving insight into the feelings of safety held by Cork residents.

Literature Review

This thematic literature review will investigate how using crowdsourcing to gather and disseminate local knowledge and sentiments about an area can enhance pedestrian safety. To achieve this, crowdsourcing will first be discussed in a broader context, outlining the characteristics and benefits of this collaborative data collection method in the digital age. This discussion will then shift focus onto crowd mapping and volunteered geographical information (VGI), with reference to how it is used for urban development. This will be followed by an extensive environmental scan of existing research that uses crowdsourcing and digital mapping to enhance safety in urban areas, specifically looking at the several ways they have been utilised to contribute towards safer navigation and investigate perceptions of safety. Finally, potential gaps in current research will be identified while addressing some of the issues and concerns with using crowdsourcing in this research and how this study aims to rectify them.

Crowdsourcing and Crowd Mapping in the Digital Age

To create a strong foundation for this research, it is essential to first understand the concept of crowdsourcing and its potential as a data collection tool in the digital age. Crowdsourcing is defined as ‘the collective generation of media, ideas, and data undertaken voluntarily by many people’ (Dodge and Kitchin, 2013). In this context, the crowd is an “undefined group of people who participate in the open call online”, and outsourcing refers to “the task assigned to a specific agent.” (Aitamurto, 2015). From this, it can be established that crowdsourcing, sometimes aptly referred to as ‘citizen science’ (Goodchild, 2008) is a method of data collection relying on volunteer contribution from the public to produce knowledge or complete assigned tasks. Crowdsourcing is an increasingly popular resource used across various academic disciplines, including the arts, digital humanities, and social sciences. The proliferation of crowdsourcing and collaborative data collection methods in research is said to be “a product of a cultural shift in Internet technologies” (Terras, 2015),

namely Web 2.0. Web 2.0 describes the shift in Internet user capability, allowing user-generated content to be integrated into online spaces, making crowdsourcing projects more accessible than ever. Crowdsourcing is said to be “one of the most significant and potentially controversial developments in Web 2.0” (Haklay, 2010) and is widely believed to have revolutionised contemporary knowledge production and data contribution in the digital age (Dodge and Kitchin, 2013) with popular examples including the crowdsourcing encyclopedia Wikipedia (Wikipedia, 2001). Crowdsourcing initiatives have been further amplified by online platforms such as Zooniverse (Zooniverse, 2009), allowing participants to contribute to various projects with tasks such as classification, transcribing, and mapping, regardless of their level of expertise or skill. The accessibility of crowdsourcing projects on smart devices and via dedicated online platforms, as well as the lack of a need for prior knowledge or experience with a task in order to participate, allows for extensive outreach to participants and is believed to result in wider and more diverse datasets than traditional methods. As crowdsourcing relies on volunteer contribution, it can also potentially be a more cost-effective data collection approach than other surveying methods. The apparent willingness of the public to contribute to crowdsourcing research for free is believed to be due to the sense of community in these projects by fostering spaces for people to “connect socially, communicate meaningfully, and contribute collectively” (Pánek, 2018).

Crowd mapping, sometimes referred to as cartographic crowdsourcing (Dodge and Kitchin, 2013), is a specialised subdiscipline of crowdsourcing. It is also commonly referred to as geo-crowdsourcing, or the production of volunteered geographic information (VGI) (Goodchild, 2007) in the context of neo-geography. Two levels of online geo-crowdsourcing can be identified; 1) dedicated crowd mapping platforms such as Ushahidi (Ushahidi, 2008), and OpenStreetMap (OpenStreetMap,2004), and 2) local projects that use geospatial tools to aid citizen participation (Pánek, 2018). Further examples of dedicated crowd mapping platforms range from Wikimapia (Wikimapia, 2006) an offshoot of Wikipedia where users can mark objects on a world map, to MapSwipe (MapSwipe,2016), where volunteers can contribute to a wide range of specific ‘humanitarian mapping’ projects. In addition to these, there are online platforms that allow users to curate custom interactive crowdsourcing maps for their own projects such as Google MyMaps (Google, 2008) and Citizen Space (Delib, 2001). The success of crowd mapping projects can be attributed to a number of factors. Similar to crowdsourcing, the accessibility of local crowd mapping can be appealing to civilians as “everyone is an expert on a locality - even if it is just their own street” (Dodge

and Kitchin, 2013). When integrated with local urban improvement projects, crowd mapping allows the citizens to get involved with their community and can also give a sense of power and a voice to citizens in government initiatives (Flores and Rezende, 2022). Online crowd mapping also provides social engagement by "creating a feeling of belonging to a certain social group community" (Pánek, 2018). This can be seen with the rise of group crowd mapping activities such as geotagging and OpenStreetMap mapping parties in online spaces (Haklay, 2010).

Uses of Crowdsourcing and Digital Mapping to Enhance Safety

Digital crowdsourcing methods have been utilised in several ways in an attempt to assist with safer navigation and experiences in urban areas. A common use of crowdsourcing in this context is to enable citizens to report crimes, incidents of street harassment, and safety hazards, which can then be displayed on a map of the area to highlight potentially dangerous zones. Crowdsafe (Shah et al., 2011) is a prime example of this, which uses crowdsourcing to enable real-time, location-based crime incident reporting through a digital map. Crowdsafe also allows users to search crime data based on location or type of crime on the map, and has a 'Safety Router' feature to map out routes that avoid highly reported areas. Similarly, Safe & the City (Safe & the City, 2017) , a UK-based live mapping application, allows users to report crimes and incidents of street harassment directly through their website, with the option to share report information anonymously or with others (Kowalchuk, 2021). Crowd mapping local knowledge is also used as a tool for urban development, and presents a novel way to highlight issues in an area. For example, the electric contractor Electric Skyline provides maps displaying the locations of street lights in urban areas across Ireland. These maps allow citizens to report any faulty or broken lighting to their local council, and in turn, shows the distribution of street lights across these areas and highlights well lit and poorly lit regions. The mobile app My Safetipin (Safetipin, 2014) uses a similar self-reporting concept to advocate for safer and more inclusive cities for women. This app uses crowdsourcing to enable people to evaluate the safety of an area based on a number of parameters such as street lighting, crowd density, and security presence (Le, 2022). Users can then view the 'safety audits' of other contributors to highlight potentially safe and unsafe areas and plan their journeys accordingly.

Further research into safer mapping has critiqued how safety considerations are neglected in the design of geographical information systems (GIS) such as Google Maps. A fatal flaw identified with these digital navigation tools, identified by many researchers (Bura et al., 2019; Islam, Hashem, and Rifat Shahriyayr, 2021) is that they will usually recommend the shortest and quickest route to reach a desired destination, which in many circumstances is not the safest. This is based on Dijkstra's algorithm (Bura et al., 2019), which finds the shortest path from one vertex to all other vertices. Many applications and studies combine crowdsourced data with other methods and resources to incorporate the safety of an area into these applications' routing algorithms. For example, SocRoutes (Kim, Cha, and Sandholm, 2014) combines geocoded posts from the social media app Twitter with sentiment analysis to identify perceived safe and unsafe areas, suggest safer routes to its users, and redirect users outside any unsafe regions. Other safety-enhanced route planners use crowdsourced travel experiences to assign 'safety scores' to areas, allowing users to customise their planned routes based on their safety preferences (Islam, Hashem, and Rifat Shahriyar, 2021). Outside of crowdsourcing, many enhanced safety route planners avail of crime report statistics to highlight problematic or high risk areas and map safer routes by avoiding these areas, such as Route-The-Safe (Soni, Shankar, and Chaurasia Sandeep, 2019). Territoria (edgargutgzz, 2023) uses subjective and objective data analysis by combining crowdsourcing safety perceptions with gender-based crime reports to highlight potentially dangerous areas in Monterrey, Mexico.

Crowdsourcing Perceptions of Safety in Urban Areas

Crowd mapping has also been used to analyse and visualise the varying perceptions and feelings across urban landscapes in many ways. Smelly Maps (Quercia et al., 2021) is a pioneering project in the field of 'sensory mapping'. Smelly Maps investigates how smell influences perceptions of an area, using geo-referenced social media data to identify common terms used to describe smells in several large cities gathered through 'smell walks'. Similarly, the concept of 'emotional cartography' is a useful method of gauging public opinions and feelings about an area. The crowdsourcing application 'Emotional Maps' facilitates this, allowing users to annotate a map with emotions they associate with a certain area such as joy and fear (Pánek, 2018). This use of crowd mapping has been recognised as a valuable tool to gain insight into citizen's perceptions of safety in urban areas. The YourGround Project (YourGround.org, 2023) uses an interactive crowdsourcing map to learn about the feelings of

safety shared by women and gender-diverse individuals in Victoria and New South Wales, Australia. Similar to Safetipin, it allows users to place pins onto a map to identify locations where they feel safe and included, or unsafe and uncomfortable. An alternative approach to learn about perceptions of safety in urban areas is image-based crowdsourcing. Often implemented through crowdsourcing games such as Como e Campina? (Candeia et al., 2017), participants are tasked with comparing feelings evoked from different Google Street View images of urban areas. This presents an engaging and novel method to learn how perceptions of safety are affected by factors such as other citizens in the area (Traunmueller, Marshall, and Capra, 2015), the built environment of the area (Candeia et al., 2017; Salesses, Schechtner and Hidalgo, 2013) and an individual's socio-demographic identity (Candeia et al., 2017).

Understanding what factors influence safety perceptions in urban areas can be complex, with many factors contributing to this. Perceptions of urban areas can vary across socio-demographic groups (Candeia et al., 2017) and results will also vary by study and the pool of participants. The characteristics of the built environment in an area, especially in urban areas, are found to majorly influence an individual's feelings of safety. (Traunmueller, Marshall and Capra, 2016) found that open, well-lit, and well-populated areas were more likely to be perceived as safe. To add to this, a study using emotional mapping carried out in Olomouc, Czech Republic found that negative emotions were more associated with areas with poor lighting, high volumes of traffic, and a lack of cleanliness (Pánek, 2018). Green and open spaces such as parks were also commonly perceived as safer or associated with more positive emotions from participants (Candeia et al., 2017; Pánek, 2018). Through spatial analysis surveys conducted in the YourGround Project, women are also found to feel more comfortable and safe in areas that they feel accommodated to through facilities such as public bathrooms (YourGround.org, 2023). According to a recent Garda Attitudes Survey, citizens tend to feel significantly less safe in urban areas at night (Copeland and Walker, 2024). Other research has also found a strong correlation between the familiarity of an area and its perceived safety (Traunmueller, Marshall, and Capra, 2016). A participant's sociodemographic identity also plays a role in how safe or unsafe they discern an area to be, as well as how they perceive and are perceived by others. From their image-based crowdsourcing study, (Traunmueller, Marshall, and Capra, 2015) found that female participants were more likely to rate images as feeling less safe compared to male participants, and that younger people were more likely to rate images as safe compared to

older people. Research following this (Traunmueller, Marshall, and Capra, 2016) found that images with groups of all men were less likely to be perceived as safe than all female or mixed-gender groups.

Critiques and Analyses of Crowdsourcing

With this research, there are several issues and perspectives regarding crowdsourcing that need to be addressed. For one, it is crucial to acknowledge the concept of the 'digital divide' as a barrier to gaining a true representation of public opinion and diverse contributions when using digital data collection methods. The 'digital divide' refers to a gap in the accessibility to Internet access, electronic devices, and digital literacy skills and training (Ragnedda and Muschert, 2013). This divide challenges the accessibility of digital crowdsourcing as a method of obtaining diverse data sets. Several studies have discussed the importance of representation and diversity in spatial data and online crowdsourcing projects. In a study using WalkRollMap.org, a web-based mapping platform that allows users to report the locations of incidents and hazards, (Bishop et al, 2023) determined that older adults are often underrepresented in crowdsourced data and VGI projects. This is believed to be because online crowdsourcing projects "often contain digital tools that can be or are perceived to be difficult for older adults to use", and describes this as "a manifestation of the digital divide". Although certain skills or previous experience are usually not required in order to contribute to these projects, digital crowdsourcing platforms can still be unintentionally exclusive as they operate on the assumption that citizens 1) know that the platforms exist and 2) possess the basic digital literacy skills needed to comfortably use them (Bishop et al, 2023). This paper also acknowledges that another potential cause for bias towards younger audiences in crowdsourced data is that they are often promoted and advertised via social media platforms with predominantly younger users.

There is also a question of the reliability of crowdsourced information and in particular crowd mapping information. The quality of data collected through crowdsourcing and crowd mapping methods is temperamental and is heavily reliant on several factors, such as public awareness and the accuracy of the information. Although research has found that VGI collected through OpenStreetMap data has reasonable positional accuracy (Haklay, 2010), the

quality and value of crowdsourced subjective data requires further scrutiny. When crowdsourcing perceptions of safety in a shared public space such as a city, it is crucial to have a diverse group of participants, especially when investigating how a person's social identity can influence results. However, this can be challenging to obtain for many reasons, including the issue of the 'digital divide' previously outlined. (Traunmueller, Marshall and Capra, 2015) add to this, finding that using a "self-selected crowd", which consists of individuals that choose to participate in a crowdsourcing project, can still lead to the underrepresentation of certain demographic groups, and in turn, can prevent having a more complex and intersectional analysis. In the case of this study, using a self-selected crowd allowed for research into how factors such as gender and age influenced feelings in urban areas, however limited analysis on other sociodemographic factors such as cultural background. (Bishop et al, 2023) echoes this stating that VGI has been shown to "exclude populations, perpetuate existing misrepresentations, and introduce general biases associated with sampling". The volume of participants in a study is also an important factor. Although a diverse range of participants is encouraged and desired by many of these projects upon reflection, (Le, 2022) emphasises that a larger number of participants in public crowdsourcing projects does not necessarily produce more accurate results. A high volume of submissions can compromise data verification, especially for smaller maintained projects, which can often result in unverified data being published (Aitamurto, 2015). With this in mind, controlled and curated groups of participants could be ideal for this type of research.

It is also important to consider some of the social implications of this research. A common concern with crowdsourcing opinions and perceptions of safety in an area is that it can inadvertently perpetuate harmful stereotypes and generalisations. Although many crowd mapping safety initiatives have positive intentions such as aiding citizen safety, inciting social change through 'counter-mapping' (Fileborn, 2020), or as tools for urban improvement, the approaches taken can unintentionally reinforce existing power dynamics rather than challenging them. (Grove, 2015) critically analyses how the use of cartographic crowdsourcing can influence perceptions of gendered spaces and security. This is done using the case study of HarassMap, an interactive mapping application based in Cairo, Egypt, used for the real-time reporting and mapping of instances of sexual harassment. This article discusses how labeling locations as 'unsafe' may reproduce and instill unnecessary fear into citizens about certain areas and lead to the negative stigmatisation of those areas. (Le, 2022) adds to this, arguing that crowdsourcing safety applications such as Safetipin can

unintentionally “reproduce other forms of socio-economic exclusion”. In many research projects in this area, commonly perceived ‘unsafe’ areas are typically lower-class (Salesses, Schechtner, and Hidalgo, 2013), marginalised, (Le, 2022), and under-maintained areas that lack funding (Pánek, 2018). These negative and classist assumptions about certain areas are arguably indulged in by the design of some crowdsourcing safety applications such as the now inactive ‘SketchTown’ and ‘GhettoTracker’ (Le, 2022), as well as more modern studies. For example, (Salesses, Schechtner and Hidalgo, 2013) asks participants to compare Google Street View images and determine which they feel appears as the safest, most upper class, and unique. Although this research can give an interesting insight into the impact of class and appearance on perceived safety, it risks reinforcing aesthetic stereotypes, and harmful and assumptive conclusions being drawn. Careful consideration needs to be taken with this research to avoid ‘technological redlining’ (Thatcher, 2013), leading to negative impacts financially and socially for labeled ‘unsafe’ areas.

From the reviewed literature, it can be seen that crowdsourcing and crowd mapping techniques can be harnessed to enhance pedestrian safety and experiences by highlighting potentially unsafe areas and hazards. This can be achieved through different methods, such as image-based crowdsourcing, emotional mapping, and through interactive crowdsourcing maps. Crowdsourcing in this fashion has also offered valuable insight into some of the components that contribute to feelings of safety in cities, from the aesthetics of the area to infrastructure and available facilities. The reviewed literature has also highlighted concerns with this research, such as the digital divide, accessibility, diversity, the validity of subjective crowdsourcing, and the social implications of the research, which need to be addressed and acknowledged through the design of this study’s digital artefact.

Methodology

This research and digital artefact aim to investigate how crowdsourcing can be used to map safer pedestrian routes in Cork City. Following the literature review, it can be seen that crowdsourcing is a valuable method to gain insight into citizens’ perceptions and feelings of safety in urban areas, highlight potentially dangerous locations based on local opinions and knowledge, and, in turn, assist with mapping safer pedestrian routes. Multiple crowdsourcing methods have been explored through the environmental scan of similar research and projects, such as image-based crowdsourcing, emotional mapping, and social media sentiment

analysis. However, the chosen medium for crowdsourcing for this research will be an interactive crowdsourcing map inspired by the design of the YourGround Project and Safetipin, allowing participants to add markers to areas that they feel are safe or unsafe and perform ‘safety audits’. With this established, this section will first outline the design and functionality of the map and how data will be collected through it. The chosen methodologies will then be compared to alternative approaches to justify these choices.

Outline of Methodology and Design of the Artefact

The proposed digital artefact for this research consists of a live web-based interactive map of the broader Cork City area, which will act as the interface for crowdsourcing information. The selected urban area for this research is Cork City, as it serves as a central urban area in the local vicinity, allowing for easy outreach to local participants with experience navigating the area. The map was created using Google Maps API, HTML, CSS, and Javascript and was hosted on a WordPress website. Inspired by the concept of the YourGround Project (YourGround.org, 2023), the map allows participants to add two types of markers to define areas around and within Cork City as either ‘Safe Spaces’ or ‘Unsafe Areas’. To gain further insight into why a participant perceives a location as safe or unsafe an additional survey element was added to the map. Once a marker is placed on the map, it will trigger a survey form with questions about why the area feels safe or unsafe (*Figure 1*), similar to the ‘safety audits’ that can be performed in the Safetipin app (Safetipin, 2014). The marker location, marker type, and the information entered into the form will then be stored in a NoSQL real-time database. The markers and associated form data can then be viewed publicly on the map. In this way the map serves as both the interface for gathering information, and as a data visualisation of perceived safe and unsafe areas. This artefact aims to integrate an element of safety to a map of Cork City using crowdsourcing to help enhance pedestrian safety, allowing users to plan their routes around safe and unsafe locations and potential hazards in the area.

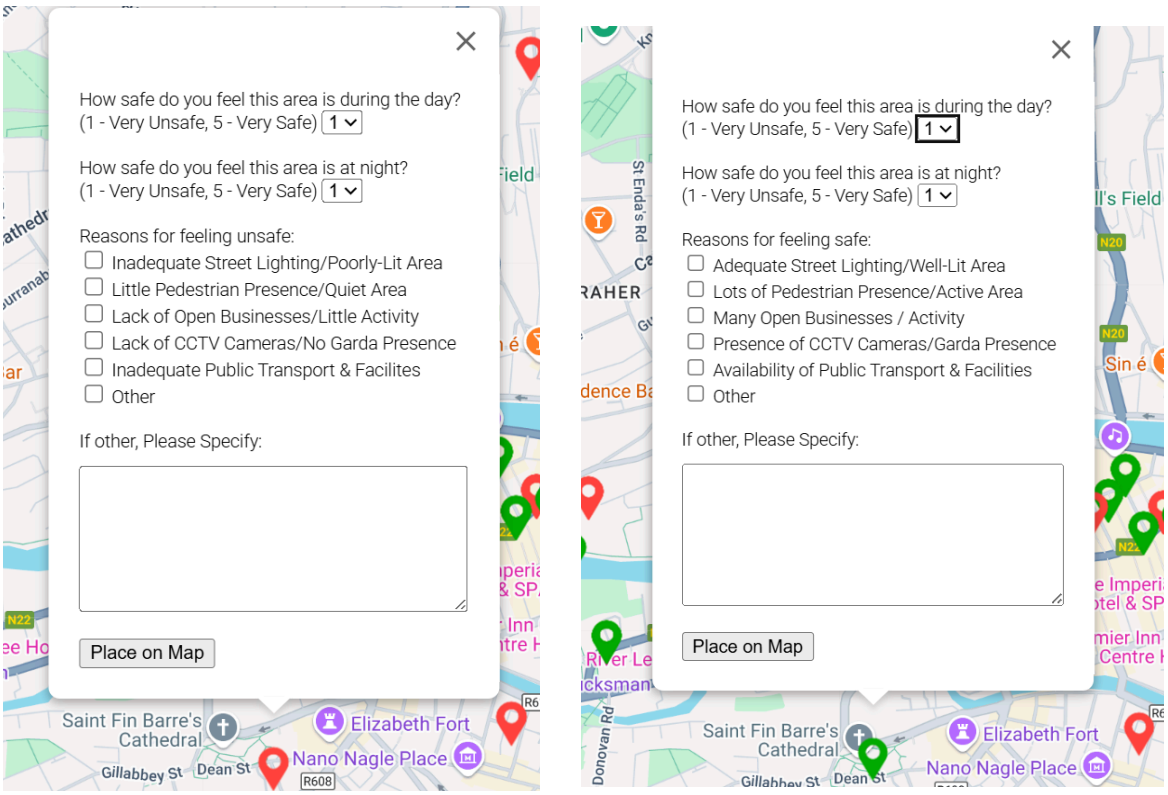

Figure 1: The forms that appears when an 'Unsafe Area' (left) and a 'Safe Space' (right) marker is placed on the map

Following the discussion of the digital divide concept, issues concerning the user-friendliness of crowdsourcing projects were highlighted, which can deter certain people from participating in these projects and skew results. To overcome this obstacle, several measures were taken to make the map and web interface as accessible and accommodating as possible to participants regardless of their digital literacy or prior mapping experience. This included a simplistic design with two marker options and a step-by-step tutorial accompanied with pictures, outlining the features of the artefact and how to contribute to the project. Although there has been criticism from other studies that marking areas as 'safe' and 'unsafe' can be reductive and oversimplified (Le, 2022), this study aims to counteract this by giving participants the ability to add context to any markers placed through the marker survey. To help users analyse map, tools for filtering the markers on the map are provided, including an interactive legend that users can toggle to view only 'Safe Spaces' or 'Unsafe Areas', and a search bar to filter for keywords based on the list of predefined reasons in the form such as 'CCTV' or 'Lighting'.

Data Collection

The research datasets will consist of data collected via crowdsourcing through the map and any markers added. These questions aim to provide further context about why a participant identifies an area as safe or unsafe and help avoid any harmful assumptions or conclusions about areas labeled as unsafe. First, participants are asked to give a rating from 1-5 (where 1 is very unsafe, and 5 is very safe) to describe how safe they feel the area is during the day, then compared to how safe they feel the area is at night. This research also examines the effect of the built environment and characteristics of the area through the survey questions. Participants can select reasons from a predefined list for why they feel an area is safe or unsafe. These reasons are based on research conducted from the literature review, including street lighting, crowd density, the presence of open businesses and activity nearby, security features such as CCTV cameras and police, and access to public transport and other public facilities. Participants are also provided with an 'Other' option and an accompanying text field to add additional comments. The variety of data collected allows for multiple types of analysis, such as spatial analysis with the locations of the markers and sentiment and textual analysis through the survey and comments.

Once the form is submitted, the marker is permanently placed on the map and instantly stored in a real-time database. The marker coordinates (longitude and latitude) are stored, as well as the type of marker, the 'Day Safety' rating and 'Night Safety' ratings, any predefined reasons selected from the list, and any additional comments. Once the map web page is loaded, the database retrieves any stored markers to be displayed on the map publicly. When a user clicks on a marker on the map, the information given in the survey can be viewed, as demonstrated in *Figure 2*. This is how the public can use the map to view other participants' contributions and gain insight into their opinions and experiences with navigating Cork City.

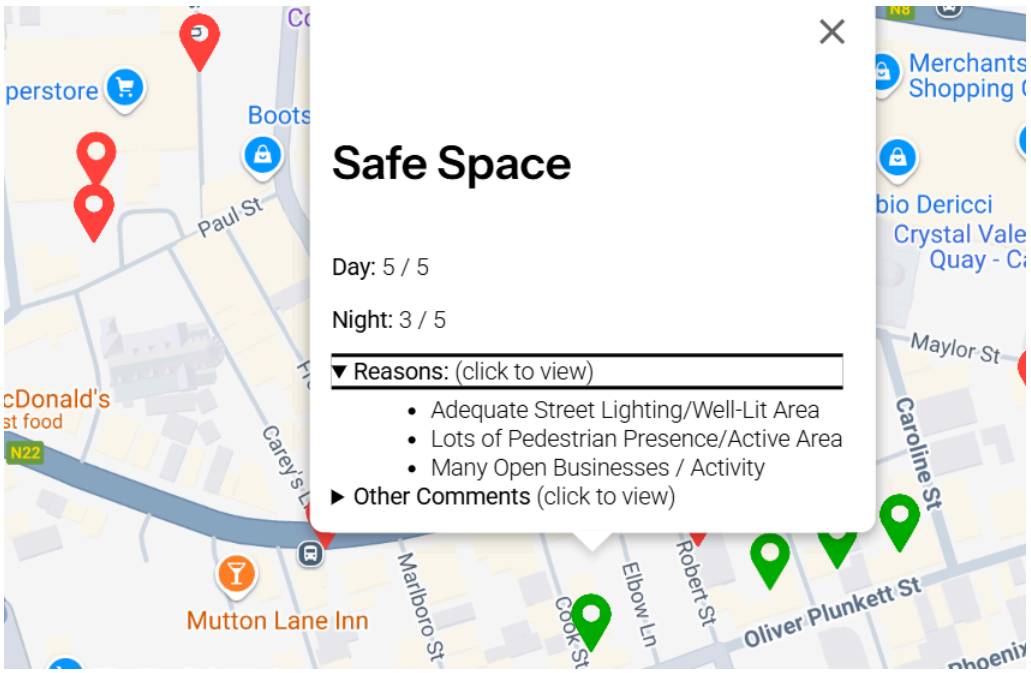

Figure 2: The data entered from the survey form for a 'Safe Space' marker, publicly displayed on the map

Ethical Considerations

To inform participants of what their involvement in this research would entail, a consent form outlining the study terms must be agreed to before contributing to the map. The nature of the crowdsourcing survey is anonymous, and no personally identifiable information will be collected through this study. As discussing issues of a lack of safety in certain areas could potentially incite negative feelings for participants, additional resources and helplines for support will be highlighted both in the consent form and on the map web page.

Recruitment Method

The chosen method for promoting the project and recruiting participants was via social media. This allowed for extensive outreach to local participants familiar with navigating Cork City. Facebook and Instagram were the chosen platforms to call for volunteers to target different user age groups for a more varied participant group. However, as this research does not require participants to give personal details such as their age, it is difficult to know if there was a varied demographic response to this research. The only criteria required for the study was that participants must be at least 18 years old, and ideally have experience navigating Cork City as a pedestrian.

Alternative Approaches

Several alternative approaches to crowdsourcing the desired data were considered for this research. For one, image-based crowdsourcing presents an engaging and innovative way of learning about safety perceptions in an area (Candeia et al., 2017; Salesses, Schechtner and Hidalgo, 2013; Traunmueller, Marshall, and Capra, 2015). This could be achieved through the use of Google Street View images. Sentiment analysis could also be used to gain further insight into the emotions and opinions of citizens regarding specific areas. This has been used for emotional mapping (Pánek, 2018), as well as for sentiment analysis using social media posts from Twitter by (Kim, Cha, and Sandholm, 2014). A map-based alternative could combine a more conventional approach to online surveys using applications as Google Forms or Survey Monkey. The collected survey data into a CSV file, where it could then be imported into layers on a map using an application such as Google MyMaps to create a static data visualisation. Ultimately, an interactive crowdsourcing map was the chosen medium for crowdsourcing for this project as it combines elements of each of the mentioned approaches. Using a map allows for an engaging and more interesting approach than a typical survey, while incorporating visual elements. The marker survey and the option for participants to add further comments to their markers allows for detailed sentiment and textual analysis. In addition to this, using an interactive crowdsourcing map also allows for continuous and real-time additions to this project, as opposed to collecting survey data within a limited time frame.

Tools

With the design of the digital artefact and the methods for data collection outlined, this section will feature extensive discussions on the different tools used to build and deploy the crowdsourcing safety map and achieve the research objectives. These include the mapping software, database, and content management system used. A comparative analysis of the chosen tools and alternative resources will be discussed to justify the selections made for this project's toolkit. Finally, there will be a discussion on how the chosen tools were applied to the proposed framework.

Comparative Analysis of Mapping Tools

First, a mapping tool was needed to create the foundation of the crowdsourcing safety map. As the digital artefact for this research is a custom crowdsourcing tool, complete control over

the customisation of the map is essential. In line with the issues discussed in the literature review, a user-friendly and inviting map interface for participants is another priority. With these criteria established, an extensive comparative analysis was conducted with some of the most popular digital mapping tools available to determine the most suitable mapping software for this research. These included Google Maps API, Leaflet, and ArcGIS StoryMaps. Dedicated mapping tools for creating crowdsourcing maps, such as Ushahidi, were also explored.

Google Maps API (Google,, 2005) is a set of mapping tools from Google with a JavaScript interface, allowing Google Maps data to be integrated into applications. This means that an interactive Google Map could be used for the base of this project using an API key, which can then be easily built upon using its extensive JavaScript API. This allows for complete customisation and control over the interface and easy integration of additional features such as customisable markers and survey forms, making this a very developer-friendly option. Using Google Maps as a base map also provides users with a familiar and easy-to-navigate mapping interface, with additional useful features such as Google Street View. Google Maps API offers a sufficient range of services and capabilities needed for this project at a free tier level. Google Maps API is also a beginner-friendly mapping software for developers, with an avid community of users on coding forums such as Stack Overflow, as well as sufficient support material available. There are many beginner tutorials and walkthrough guides available in the Google Cloud Console, as well as through online educational resources such as W3Schools. One downside of Google Maps API is that it does not provide built-in forms. However, these can be custom built using HTML within the JavaScript code of the map.

Leaflet (Leaflet, 2011) is another strong choice for this project, comparable to Google Maps API. Leaflet is a lightweight free and open-source JavaScript library used for building mapping applications. Similar to Google Maps API, Leaflet offers extensive JavaScript support for full control over customisation and many tutorials for different user levels. Leaflet also has a large community of users, with hundreds of community-made plugins available to download online. A downside of Leaflet is that it does not have built-in forms, however Leaflet also supports HTML and CSS, to make custom-made forms. Leaflet also does not have its own map interface for the base map. Instead, script tags can be used to easily implement a source map from an application such as OpenStreetMap or a more local map from the Cork City Council. It can also be more challenging to integrate real-time features

for storing markers live with Leaflet than Google Maps API as it would require more configuration.

ArcGIS StoryMaps (Esri, 2019) is an app within the ArcGIS ecosystem, a geographical information system (GIS) written in C++. ArcGIS has some features suitable for a crowdsourcing map, such as Survey123 or Collector for ArcGIS, which could be used to create marker surveys. ArcGIS also offers high-quality interactive maps for the map interface. One pitfall with ArcGIS StoryMaps for this application is that it allows minimal customisation with no code access. StoryMaps also does not support any real-time capabilities and must be updated manually, which is not ideal for this project. In addition to this, ArcGIS has a much steeper learning curve compared to Google Maps API and Leaflet.

As a dedicated crowdsourcing map platform, Ushahidi (Ushahidi, 2008) has its own built-in forms and data collection tools that are ideal for the survey element of the map. Ushahidi uses OpenStreetMap data for the base map, providing a clean and straightforward user interface. However, this platform does not offer the same level of customisation or control as other platforms and would not be suitable for the proposed digital artefact. Ushahidi is instead ideal for professional, larger-scale mapping projects.

From comparing these mapping tools, it was clear that Google Maps API and Leaflet were the most suitable choices for this application. Both applications have sufficient JavaScript capabilities and also support HTML and CSS, allowing for full control over customisation. They also have a variety of community resources, such as tutorials and plugins available. It was decided that Google Maps API would be the better fit for this project, due to the high quality and immersive Google Maps base map, with valuable additional features such as Google Street View and navigation buttons to enhance user experience. This mapping tool suite will be used in conjunction with HTML to create the survey form structure, CSS to assist in creating a user friendly and visually appealing interface, and JavaScript to add further interactive elements to the map.

Database and Web Implementation

A real-time NoSQL database was connected to the map using JavaScript to store marker data. A real-time database was chosen for this live crowdsourcing map so that markers could be

viewed publicly immediately after being placed on the map and would not need to be updated manually. Local storage was not used here as it would not have allowed markers added to the map to be displayed publicly. As there are optional sections in the marker survey, such as the 'Other Comments' field, using a NoSQL database also allows for more flexibility, rather than a structured SQL database. Google Firebase was used to create and host the real-time database, as it could be easily integrated into the Google API Map. Using Google Firebase also eliminated the need for a backend for storage, keeping the structure of this project as lightweight as possible. The database can be monitored through the Google Firebase Console. From here, all the marker data is stored in a JSON format and can be viewed and deleted if necessary. (*Figure 3*)

Figure 3: A screenshot from Google Firebase showing the stored information from a marker in the real-time database

To make the project as accessible as possible for participants, the map was deployed using a website rather than an app. This avoids the need for participants to download an app onto their personal devices in order to contribute to the study. The chosen content management system for this project was WordPress.org. WordPress has highly customisable features and multiple themes to create a simple and visually appealing website for participants. WordPress also allows for easy map integration into a web page via the Custom HTML content blocks. The map was implemented into a WordPress website titled 'safescapecorkcity.com' and hosted via the web hosting service Reclaim Hosting.

Application of Tools

With this toolkit selected, the chosen tools were then applied to the architecture outlined in the methodology section to create the crowdsourcing safety map. First, the interactive Google Maps base map and corresponding API key were created in Google Maps API. With this, an HTML file was created, and the maps API key was integrated into the code using script tags, forming the foundation of the map. This code was written and tested using Visual Studio Code. The code for the map and other features, such as the buttons, search bar, and interactive legend, was implemented into a WordPress website using a 'Custom HTML' content block. HTML and CSS were used to create two buttons for users to select a marker type to add to the map. Depending on the button selected, either an 'Unsafe Area' (red) or a 'Safe Space' (green) will be added once the map is clicked. By default, the unsafe area marker is selected. JavaScript 'event listeners' are used to detect when a user clicks on the map. When this happens, a temporary marker is added, and the survey form for the selected marker type appears in a pop-up 'info window.' The survey forms were created with HTML, using dropdown lists, checkboxes, and text fields. Once the user fills out the marker survey and the form is submitted, the temporary marker is removed from the map and replaced with a permanent marker that can be viewed publicly. The data submitted through the form, marker type, and coordinates are stored in a JSON format in the Firebase real-time database. A global listener is used with Firebase to actively listen for new form submissions, allowing for live storage and map updates. Once the map web page is open, Firebase retrieves all stored markers loaded onto the map. Event listeners are used again to detect when a user clicks on a marker added to the map. This then triggers another pop-up info window, displaying the survey data associated with the marker. The basic architecture of this system is visualised in *Figure 4*.

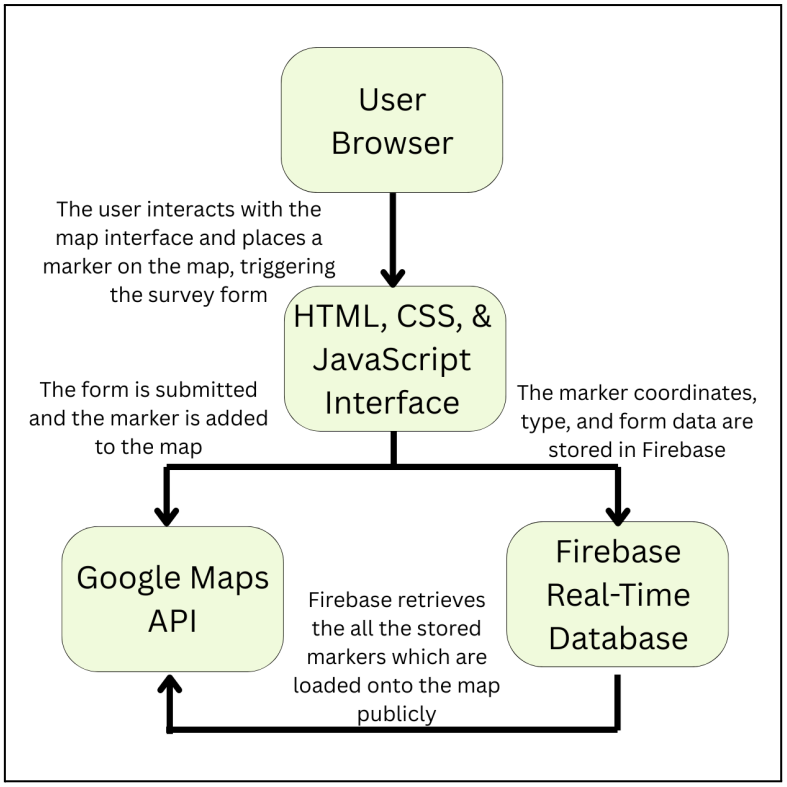

Figure 4: The system design of the map using the chosen tools, outlining how markers are added, stored, and displayed on the map

Analysis and Reflection

The main objective of this research was to examine how crowdsourcing can enhance safety and assist mapping safer routes for pedestrians in urban areas. This was addressed through the digital artefact, a custom crowdsourcing tool which collects user-submitted data about feelings of safety in areas across Cork City. The established idea of this artefact is to identify and visualise locations that are perceived as safe or unsafe throughout Cork City on a map, so that pedestrians can navigate the area assisted by local knowledge about the area and choose their routes accordingly. As mentioned, the crowdsourcing map SafeScape was hosted on a website and promoted through the social media platforms Facebook and Instagram to recruit participants. It will be noted as the project is anonymous and does not collect any personally identifiable information, and as the design of this research enables a single participant to place multiple markers, it is difficult to identify the demographics or the size of the participant pool. Over the course of a two week period, 43 markers were added to the map. 22 of these markers labelled ‘Unsafe Areas’ and 21 identified ‘Safe Spaces’. This balance of safe and unsafe markers offers deep insight into both positive and negative perceptions of locations throughout the broader Cork City area. In addition to this, the design of this

crowdsourcing research allows for nuanced and layered results, combining geospatial analysis with marker placements, sentiment analysis through the data collected from the marker surveys, and further textual analysis with any provided comments.

Geospatial Analysis

As well as providing the interface for crowdsourcing the data, the SafeScape map serves as an interactive data visualisation, showing how local citizens perceive different areas within Cork City through the placement of 'Safe Space' and 'Unsafe Area' markers. By examining the spatial distribution of these markers, patterns in safety perceptions across the area can be identified. As seen in *Figure 5*, the majority of the markers, for both safe and unsafe areas, are heavily concentrated towards the main central streets of the city, including Oliver Plunkett Street and Patrick Street, and are dispersed more sparsely in the outer areas of the city. This may suggest more activity in these areas or stronger feelings regarding safety issues.

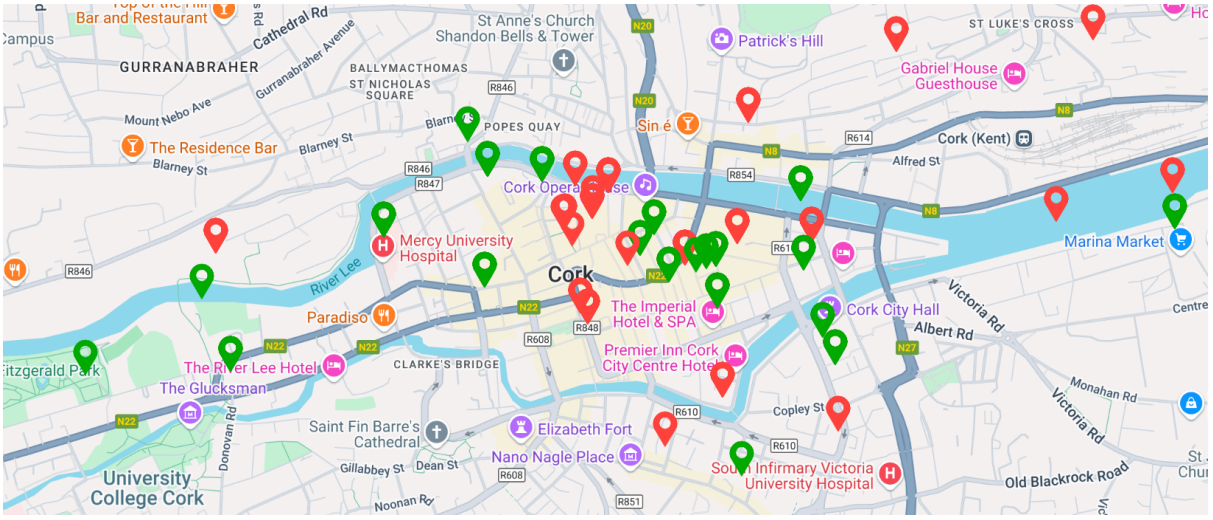

Figure 5: A zoomed out view of the SafeScape map of Cork City and the 43 placed markers

Clusters of safe or unsafe markers in certain locations may indicate common feelings and perceptions towards the safety of these areas. Two of the most marked areas are highlighted in *Figure 6*. These are Paul Street, which had six 'Unsafe Area' markers placed on the street and associated side streets and alleyways, as well as Oliver Plunkett Street, which had four 'Safe Space' markers. In the six unsafe markers placed around Paul Street, the most commonly given reasons were a 'Lack of CCTV Cameras/ No Garda Presence' appearing across three markers, 'Little Pedestrian Presence/ Quiet Area' appearing three times, and 'Inadequate Street Lighting/ Poorly-Lit Area', appearing twice . Comments attached to these

markers describe the area as ‘rough’ and once again refer to ‘antisocial behaviour’, emphasising that they would avoid the area at night. Another comment stated ‘as a woman, I wouldn't feel comfortable here alone when it's quiet’. These markers have an average day safety rating of 2.3 out of 5, and an average night rating of 1.3 out of 5.

From examining the reasons listed in the ‘Safe Space’ markers placed along Oliver Plunkett Street, it can be seen why this area is commonly considered to be safe by citizens. The perceived safety of this area seems to mainly be due to this being a busy central street, with activity due to open businesses and a strong crowd presence during the day and at night. Pedestrian presence was selected in all four markers, whereas open businesses and activity was listed three times. One safe marker comment confirms this, adding that the area is ‘usually busy’. The quality of street lighting in the area also heavily attributes to these results, being a reason selected in three markers. This area is also highly scored with the day and night safety ratings, with an average of 4.5 and 3.5 respectively. As seen in *Figure 5*, an ‘Unsafe Area’ marker is placed on Robert Street, a side street off of Oliver Plunkett Street, emphasising the complexities of safety perceptions across urban landscapes.

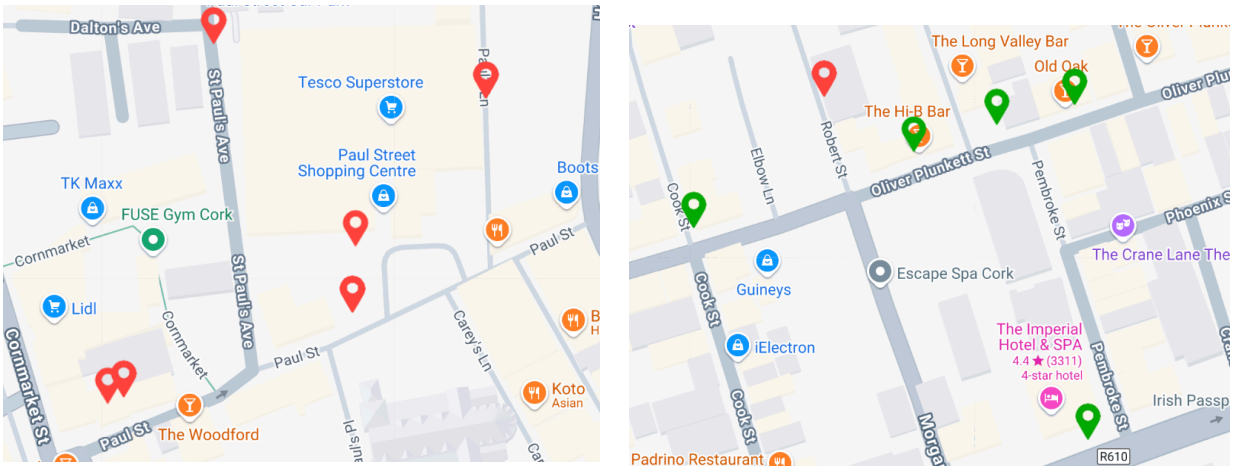

Figure 6: Zoomed in sections of the map, highlighting Paul Street (left) and Oliver Plunkett Street (right)

The placement of many of these markers affirm the findings of the research explored in the literature review. For example, two parks within Cork City are marked as safe spaces, being Fitzgerald’s Park and the Cork Skate Park. This is in line with research that green and open spaces are associated with more positive feelings and are often perceived as safe (Candeia et al., 2017; Pánek, 2018). However, Bishop Lucey Park, a park located on the Grand Parade in

the city centre, has two unsafe markers, one of which stating that the area can be rough at night in an additional comment. This ties in to how the anticipation of antisocial behaviour and crime can strongly influence how safe an area feels for citizens (Copeland and Walker, 2024). This also demonstrates the complexity and layers of safety perceptions, and may suggest which factors take priority in how safe an area feels.

The location of safe and unsafe markers alone offers great insight into both the opinions and experiences of Cork City locals, and general perceptions of urban areas. Overall, busy areas such as Oliver Plunkett Street, are commonly perceived to be safe. Several areas near public facilities that are open until late hours such as universities (University College Cork), hospitals (Mercy University Hospital and South Infirmary Victoria University Hospital), and council buildings (Cork City Hall) were marked as safe spaces. Side streets and areas that are usually quiet and poorly - lit such as the Docklands were commonly marked as unsafe.

Survey Results

The survey attached to the markers provides context to the placement of markers, and allows for more complex sentiment analysis. To examine this data, marker data is stored in a realtime database in Firebase in a JSON format. This was cleaned and added to a spreadsheet in MicroSoft Excel for further analysis and to create data visualisations (see Appendix A). First, participants were asked to describe on a scale from 1 to 5, of how safe they feel an area is during the day, compared to how they feel that area is at night, where 1 indicates that an area feels very unsafe, and 5 feels very safe. Across the 22 unsafe areas there was an average day safety rating of 3, and an average night safety rating of 1.59. The 21 Safe Spaces were given an average day safety rating of 4.76, and an average night rating of 3.52 (*Figure 7*). Between both safe and unsafe spaces, participants felt less safe in an area at night than during the day. These numbers could suggest that the feelings of unsafety and discomfort in ‘unsafe areas’ is heavily influenced by experiences and feelings at night. Out of the 22 unsafe areas markers, 16 had a day rating from three to five (suggesting that an area feels neutral, somewhat safe, or very safe) however they have a night safety rating from one to three (suggesting that an area feels neutral, somewhat unsafe, or very unsafe). So even if an area is regarded as moderately safe during the day, this can be skewed by how the area feels at night. This demonstrates the impact of the time of day in how safe an urban area feels for citizens,

and implies a need for better facilities in these areas to accommodate these sentiments, such as adequate street lighting, and a stronger police presence at night.

	Average Day Safety Rating	Average Night Safety Rating
Safe Spaces	4.76	3.52
Unsafe Areas	3	1.59

Figure 7: The average 'Day Safety' and 'Night Safety' Ratings given to 22 unsafe markers and 21 safe markers

The second section of the marker surveys asks participants to select reasons from a predefined list of reasons inspired by research conducted in the literature review to explain why they feel their chosen area is safe or unsafe. The results of this portion of the survey gave insight into how certain characteristics of the built environment influence how an area is perceived. These included 'Lack of/Presence of Street Lighting', 'Lack of/ Lots of Pedestrian Presence', 'Lack of/Presence of CCTV/ Garda Presence', ' Lack of/Presence of Public Transport & Other Facilities', and 'Lack of/Presence of Open Businesses and activity'.

Across areas marked as safe, the most commonly listed reasons were pedestrian presence, appearing in 15 markers, nearby open businesses and activity, also appearing 15 times, and the presence of Street Lighting, appearing 13 times. The presence of CCTV and security, and access to public transport and other facilities were not seen as important as these factors, appearing eight and five times respectively. This is visualised in *Figure 8*.

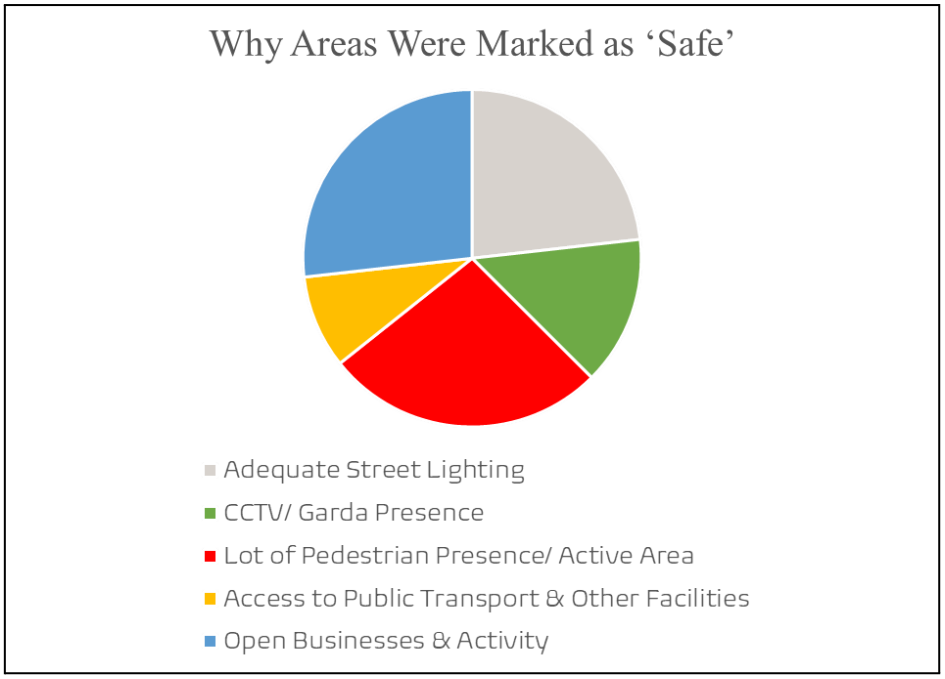

Figure 8: A pie chart comparing the different reasons listed in 'Safe Space' markers

In areas marked as unsafe (*Figure 9*), however, the most listed factors were little pedestrian presence, mentioned 11 times, poor street lighting, mentioned 10 times, and a lack of CCTV and security presence, mentioned eight times. Similarly to the 'Safe Space' markers, access to public transport and other public facilities did not significantly contribute to an area feeling unsafe and uncomfortable, only being listed once. However, there is a clear difference between how open businesses and activity were viewed between safe and unsafe spaces. The presence of open businesses and activity in an area were widely attributed to that area's safety. In contrast, the absence of open businesses or activity in an area, did not seem to make the area feel less safe, as it was only listed four times.

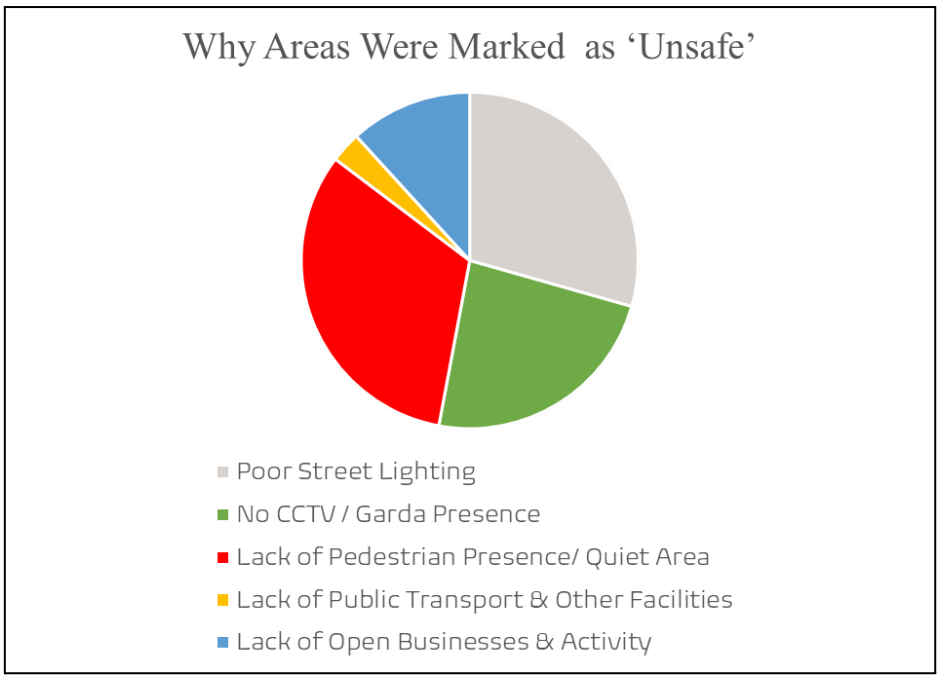

Figure 9: A pie chart comparing the different factors listed in 'Unsafe Area' markers

Finally, participants were given an optional comment text box, to elaborate on any of the reasons they selected from the list. This could also be used with the 'Other' option from the checkbox list of reasons. This feature was not heavily utilised, as out of the 42 markers placed, only 14 had additional comments. Nine of these comments are attributed to 'Unsafe Area' markers, and five to 'Safe Space' markers. These comments allow for additional perspectives and more complex analysis through textual analysis. Using the text mining and visualisation tool suite Voyant, a word cloud (*Figure 10*) was made for the unsafe marker comments, to highlight commonly used words and sentiments.

Figure 10: A word cloud visualisation, showing the most commonly used words in the comments attached to 'Unsafe Area' markers

After removing common stop words from the comments, the most used 'unique' words can be seen. In this visualisation, the how big the word appears on the visualisation indicates how frequently it was used. 'Night' was the most commonly used word from the 'Unsafe Area' markers, appearing eight times across seven comments. This backs up the data collected from the day and night safety ratings, reaffirming that people's perception of how safe an area is is heavily based on night time experiences. Other common words highlight how negative activities influence perceptions of areas, with frequent mentions of 'antisocial behavior', and 'crime'. One comment mentions specific offences such as shoplifting and public urination. Other commonly used words highlight negative sentiments about these areas, such as 'uncomfortable' and 'rough'. 'Avoid' is another commonly used word here, showing how negative perceptions and connotations of certain locations can influence how people navigate an urban area.

Reflections

It should be noted that the results of this are subjective, and that using this map to navigate Cork City does not guarantee safety in labeled safe areas, nor does it lead to unpleasant or dangerous experiences in unsafe places. However, this digital artefact and research still answers the research aim of crowdsourcing local knowledge, opinions, and experiences to

offer insight into and highlight potentially safe and unsafe locations within Cork City. This data adds an interesting element to the google map used for the base of this project, which could be used to supplement routing planning tools for confident and knowledgeable navigation.

Conclusions

This research has resulted in the creation of a live crowdsourcing tool to collect data about safety perceptions in Cork City. This interactive map provides substantial insight into locations throughout the study area that are seen as safe or unsafe, which could be a valuable resource for planning safer routes for pedestrians. This concept of gathering local opinions and perspectives through online crowdsourcing adds an important element of safety missing from popular mapping and route planning applications, making this an ideal tool for those unfamiliar with the area or vulnerable groups to navigate the city with more confidence and knowledge. Inspired by similar international projects such as Safetipin and the YourGround Project, SafeScape also provides a space for Cork City residents to voice their opinions and concerns about the safety and facilities in their local area. This research highlights potential issues regarding the infrastructure and available facilities across various locations throughout the city, such as inadequate street lighting and a lack of CCTV and security measures. By mapping the sentiments and concerns held by local residents, this map could also be utilised by town and city councils to identify issues for future urban development and improvement.

The analysis of 43 user-contributed markers reveals interesting spatial and thematic patterns in the perceptions of different areas across Cork City. In particular, these contributions emphasise how particular areas such as Paul Street are commonly perceived to be unsafe. Through the textual analysis of the comments, this study also identifies how the anticipation of ‘antisocial behaviour’ and crime affects safety perceptions throughout the city, and highlights which areas have these negative associations. The results from this research strike many parallels with the findings of the reviewed literature. For one, the stark differences between day and night safety ratings affirm how areas people typically feel less safe in urban areas at night. This research also offers insight into the factors of the built environment that contribute to an area feeling safe and unsafe. This stressed the importance of adequate street lighting, CCTV, and security features to enhance safety, as well as how activity in an area with open businesses and a crowd presence can make citizens feel more comfortable.

Using Google Maps API, JavaScript, HTML, CSS, and a No SQL database, a lightweight and scalable crowdsourcing map was created, with scope for future adaptations. A limitation of this study is that it does not examine how socio-demographic factors such as age, gender, and nationality influence perceptions of safety in an area. Further research developments could accommodate this by adding questions about a participant's identity to the marker surveys. Additional filtering capabilities could then be added to the map interface to allow users to see markers placed by different age demographics and gender identities. As the design of this crowdsourcing tool allows for continuous data collection, another avenue for this research would be to incorporate time stamps to add markers to facilitate temporal analysis and examine how safety perceptions evolve over time. Finally, a routing service such as Open Route service could be integrated into the map to enhance safer navigation. This could be used to enable users to map custom routes based on the markers on the map, such as avoiding unsafe markers, or prioritising well-lit areas.

Appendix

Appendix A: Marker Data Excel Spreadsheet

A cleaned version of the dataset of user-submitted markers, including safety ratings, reasons selected, and added comments, is available in the following file:

SafeScape Marker Data

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