Chapter

A GIS-Based Risk and Safety Analysis of Entrance Areas in Educational Buildings Based on Students' Experience

Sara Shirowzhan, Laurence Kimmel, Mohammad Mojtahedi, Samad Sepasgozar and Jack Peacock

Abstract

The architecture of educational buildings is required to meet the contemporary needs and follow regulations concerning safety issues in an intelligent, resilient, and systematic manner. However, the current literature generally neglects to identify geo-referenced risks within GIS environment based on the users' perceptions of educational environments. This research aims to present a newly formulated risk evaluation criteria for assessing the spaces within and outside educational buildings. This chapter investigates students' experience of using different micro-spaces, architects' predesign assumptions and expectations of the spaces, and post-design assessment of the spaces. Two case studies of educational spaces within University of New South Wales campus in Kensington, Sydney was selected, and the questionnaire method was employed to collect data from students, who routinely use the selected areas. By comparing the results of the two buildings and mapping them in GIS, it is suggested that feelings of safety and security can be increased via improving the building features and enhancing the building control and security control, for example, installing CCTV and other security infrastructure. Data-driven findings mapped into GIS create a prototype for the identification of problematic areas on a map. The results help decision-makers to understand risks and strengthen risk reduction strategies. This work is also a step towards smarter buildings and enhanced preparedness for an effective response to a security threat, both minimal and extreme.

Keywords: smart cities, resilient cities, safe buildings, public building, GIS

1. Introduction

Crime prevention through environmental design (CPTED) is an established design methodology that aims to reduce the opportunity for crime, fear, and disorder within the built environment. Pioneered by US architect Randall Atlas, this method for designing recognises the intended use of a space in a building and the opportunity to use design elements to achieve security goals without the imposition of traditional security mechanisms (e.g. alarms, gates, and locks). It is important to note that this method can be applied not only to new design projects but also retroactively for existing sites [1]. The CPTED establishes a framework for assessing a program or building, aiming to consider and classify assets, threats, vulnerabilities, and countermeasures, working to establish the security needs and requirements of a site. Through this site assessment, architects and designers should be able to follow guidelines that ensure the safety of clients and users from a range of security threats, from basic petty crime to more extreme terrorist attacks [1].

However, this design methodology is a general guideline and does not provide specific, analysed case studies nor those showing a mapping of how crime and unsafe areas are linked to user perception. This study aims to provide a methodology for mapping an area or location and addresses questions of perceptions of safety in a public, educational environment. The first question aims to identify whether a student feels safer in an outside public space in front of the building or inside the building. What are the factors that would make one access feel safer than another? Do students feel safer if they are more visible by other students and by staff members (directly or indirectly through closed-circuit TV or CCTV cameras)? Outside the building, it is assumed that students have clear vision of the surrounding areas and have the possibility to take different paths if they notice something unusual in the area. The interior of the building could be perceived as more protected, but it is more constraining and generally more difficult to locate a safe space when faced with a threat inside a largely open-plan public building.

Within the interior of the ground floor, what are the factors that would make one location feel safer than another? Considering the factors that might influence the response of students (e.g. gender, time of day or night studying, cultural background, familiarity with area), is it possible to have a map that represents the feeling of safety of the community of users of a building? If yes, what is the accuracy of this map? This study will provide guidelines to help designers and stakeholders in evaluating the perception of safety of the users of their public buildings and also assist them to identify areas in a public building where the perception of safety is low, in order to enhance the well-being of the users.

2. Literature review

This section reviews relevant papers in three main areas to develop an interdisciplinary framework to be a base for conducting a systematic survey. Three main areas are selected, and relevant papers are reviewed as follows.

2.1 Resiliency in public buildings and international frameworks

Safety and security in public buildings is a considerable phenomenon that has been widely debated. The aim is to anticipate hazards in order to alter the frequency and intensity of hazards and disasters within public buildings. This can affect considerably built-up, urban environments, particularly public buildings such as university campuses (Basher, 2006; Tozier de la Poterie and Baudoin, 2015). Disaster risk management studies have focused on natural disaster risks such as fire, floods, and storms, when man-made disasters such as a terrorist attack have been neglected. Using a review of existing literature, this study explores international frameworks for disaster risk reduction (DRR) and resiliency enhancement in public buildings. Methods exist to significantly reduce the number of disaster risks and loss of life, livelihood, and health in the economic, physical, social, cultural, and environmental assets of persons, businesses, communities, and countries [2]. International frameworks for disaster risk reduction and resiliency have very ambitious targets to reduce global hazard incidents in terms of the number of people affected globally and direct disaster economic loss in Gross Domestic Product and the number of countries with high national and local disaster risk [2]. Hence, this research will review disaster risk reduction and building resiliency associated with safety and security within the Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR), analysing how public buildings such as university campuses are addressed.

In Australia, local councils are responsible for approving the development of most projects and building plans [2–4]. They are important for reducing risk in planning and building; they must pass bylaws on building regulations and prepare land use plans and emergency response plans. This research seeks to measure public buildings' approaches and synergies with the Sendai Framework for Disaster Risk Reduction 2015–2030. Local councils have emphasised the need to focus on urban resilience; however, there have been insufficient tools and techniques to measure public buildings' resilience efforts with clear quantitative decision-making tools [5].

There are four main priorities explained in the Sendai Framework. These following priorities are split into national/local levels and global/regional levels. It enables effective macro- and micromanagement to tailor towards different areas:

Priority 1: Understanding disaster risk.

Priority 2: Strengthening disaster risk governance to manage disaster risk.

Priority 3: Investing in disaster risk reduction for resilience.

Priority 4: Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation, and reconstruction.

These priorities of the Sendai Framework for Disaster Risk Reduction are the background framework of this chapter investigating a connection between safety in building and resilience.

2.2 Safety-oriented design

Resilience in the case of a university building means that the design is keeping users and assets safe, and at the same time, users are not anxious in their everyday life by the safety-oriented design. The university building stays open and welcoming to staff, students, and temporary guests. Australia's current counterterrorism guidelines focus on securing crowded places, and universities are considered in this category, especially during special events like open days.[1] While the application of the guidelines to a particular site is informed by criteria set out in [6], the strategies adopted in specific cases—including the extent to which "openness-friendly" measures are adopted—rely on relevant design stakeholder engagement. The outcome of the literature review on safety-oriented design in Australia, the United Kingdom, and the United States[2] is that two broad approaches to securing public spaces can be identified: *enclosing* and *layering*.

Enclosing, also known as "fortressing" (or "traditional target hardening"), is a defensive strategy that focusses predominantly on denying access to a target through exclusion. In its most elementary form, enclosing secures public domains via physical or artificial barrier techniques such as bollards and security walls ([1]: 5, 13).

---

[1] As of 29 June 2019, Australia's ANZCTC has published 16 counterterrorism related guidelines and reports: https://www.nationalsecurity.gov.au/Media-and-publications/Publications/Pages/default.aspx

[2] As of 29 June 2019:

- 13 counterterrorism related guidelines and reports have been published in the US (FEMA website). Those of most relevance to the present discussion are those published by Federal Emergency Management Agency (FEMA): FEMA 426 Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings [7] and FEMA 430 Site and Urban Design for Security [8].
- 25 counterterrorism related guidelines and reports have been published in the UK (gov.uk website). The CPNI (Centre for the Protection of National Infrastructure) issues guidelines for important and sensitive assets (CPNI website). Those of most relevance to the present discussion are the guidelines issued by HM Government [9, 10] and by the Royal Institute of British Architects [11].

Typically, the implementation of this design strategy sees significant standoff distances between entrance points and the building, facades constructed of hardened materials, and the building's interior protected by both secure outer and inner perimeters ([12]: 2.23).[3]

Enclosing has proved a common strategy under the US counterterrorism guidelines for many years, notably in the safeguarding of schools and college campuses.[4] While its implementation offers a very direct (and efficient) enhancement of safety, in design terms it poses significant challenges to maintaining physical and psychological openness. As Randall I. Atlas notes, "[c]onsider the 1970s fortressing in schools and the windowless and sterile physical structures that emerged. That fortressing sent a message of paranoia and fear" ([1], 283).

In contrast to enclosing, layering is a security strategy that focusses on protecting a site by introducing multiple layers of complementary protective measures. The strategy capitalises on redundancy in a site's security design: if implemented correctly, it ensures that the failure of any single layer—which may consist of different security measures—will not significantly compromise the overall security of the building. Rather than reducing the likelihood of a security threat, the goal of layered security is to reduce the likelihood of a *successful* threat. Also known as "security in depth" ([15], 14), strategies of layering consider a building's security both in its proximate context and in its internal layout. Under the US counterterrorism guidelines, FEMA outlines a layered security comprising three layers:

- "First Layer of Defence": comprises barriers (commonly at a property line or sidewalk/curb line) ([7], 2–12). In the context of HV mitigation in front of a building, this first layer may take the form of permanent or removable (but well-designed and integrated) bollards.

- "Second Layer of Defence": extends from the perimeter of the site to the exterior face of a building ([7], 2–12). "The most basic elements of architecture are themselves part of the security systems for buildings: walls, doors" ([16], 16).

- "Third Layer of Defence": commonly comprises the building's interior and separates unsecured from secured areas ([7], 2–12).

More nuanced a security strategy than the defensive "shield" of enclosing, layering—in principle—aligns more naturally with objectives of openness in public building security and thus with objective of resilient design.

2.3 Mapping of perception of safety

Existing research mainly focuses on crime mapping and safe zone mapping in public spaces. Crime mapping is one of the main purposes of recent crime analysis. However, the use of maps for criminology relates to predigital and satellite mapping techniques, when maps were 2D and containing less information.

Since the early 1980s, there has been a resurgence in the interest for three-dimensional analysis of unsafe places and crime areas in order to identify high-risk areas and to visualise information on unsafe areas [17, 18]. When geographical information systems (GIS) were developed in the 1990s, policy makers, including law enforcement departments, started learning more about their capabilities. Policy

[3] Among others, the enclosing strategy has encouraged forms of perimeter protection such as 'Forced-Entry-Ballistic Resistant' (FE-BR): see Whole Building Design Guide [13].

[4] FEMA has published guidelines specifically in relation to school security [14].

makers started learning the basics of location analysis and spatial information in order to identify and develop methodologies to prevent and protect public areas from crime.

The recent literature recommends the use of location-based systems and GIS to detect high-risk areas and the possibility of quick responses to the crimes [19, 20].

Emerging technologies such as advanced sensors, apps, and advanced GIS features are helpful for safety and crime analysis. Different layers of GIS can show the historical or current high-level crime areas and unsafe locations. Relevant data seeks to identify spatial patterns related to space, people activities, location features, and time. However, the utilisation of such technologies now updated [21, 22] and the upscaling to advanced technologies is slow. Several unanswered questions are mentioned in the literature and are knowledge gaps such as [17, 21, 22] what methods such as univariate methods can be used to extrapolate location-based patterns in small public areas. Crime and safety location analysis and mapping demonstrate, measure, analyse risks, and evaluate or rate locations. The analysis also helps to interpret what should be done in high-risk areas, what should be the priorities, and what should be improved. Locating, mapping, and geo-referencing may reveal patterns that can be used to model space and time in predicted future situations [17, 20].

The development and utilisation of GIS for crime and safety analysis is a slow process. The literature gives a couple of reasons for such a slow process, such as the costs, hardware, and software available to public place managers, and the complexity of the system development process [17, 23, 24]. However, it is known as a powerful tool to support crime and unsafe place analysis including the day-to-day activities of place users [23]. At the technical level, GIS uses vector data representing the fundamental units of spatial data such as points, lines, and polygons. The point is a discrete position similar to a pin or flag on a 2D drawing. The line also represents more than two points on a map which is the same as a normal line or a set of points in one line representing the boundaries and walls. The complicated feature can be a polygon representing a geographic area in the selected public building with a set of line segments [25]. Buildings, parks, or lakes are just a few examples. The GIS environment includes a series of elements corresponding to a data bit or a record which should be previously defined as an attribute. **Figure 1** shows the proposed workflow to select the area, collect data, and populate the geodatabase for the safety and crime analysis in this paper.

Since the safety and crime analysis is a complicated analysis, the vector data is not enough for modelling and accurate interpretation. Therefore, the second type of data is required, namely, raster data model. Raster data is RGB or pixel-based data

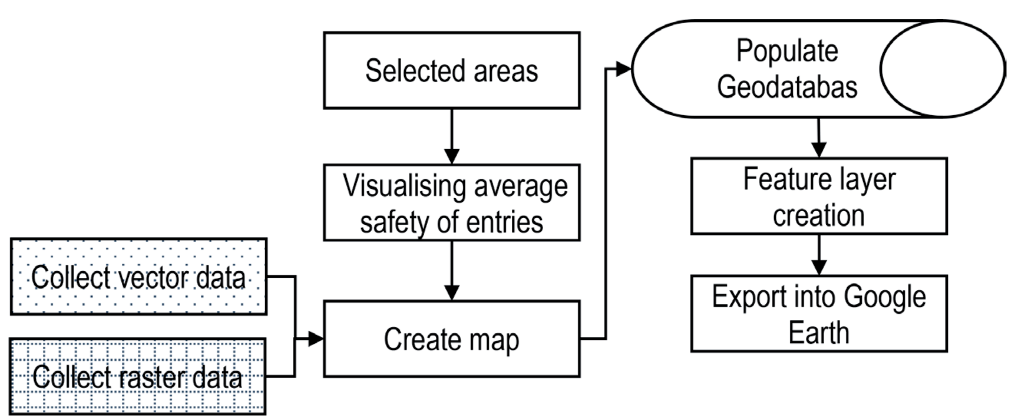

Figure 1.
The proposed workflow for creating and updating the maps in GIS environment.

such as an image. This type of data can be collected from different sources such as aerial or satellite photos. Similar to the vector data, the data record has an attribute; it means that each pixel linked to an attribute value. The combination of both vector and raster data sets will enrich the designed GIS model by including the qualitative data related to geographical data.

Since the public space is selected in an educational area, the literature in the education is also reviewed. The student feelings and attitudes that are obtained by a university's environment can be called the university climate in terms of safety (Loukas, 2007). This is related to the concept of safety and safe learning environment. The quality of the physical environment and a safe university helps students to flourish socially and emotionally.

Previous studies focused on several factors influencing the safety climate in an education place (Loukas, 2007). However, details of the physical environment have been largely ignored. Furthermore, different zones in a large university have different attributes, and the student's feelings are not the same. A question has remained on what main factors potentially influence the university climate. Particularly, what characteristics may contribute more in making feeling higher safety in buildings by students (**Table 1**).

Previous studies explained that the quality of the educational building and infrastructure may affect the student achievement; additionally, this also could affect both students and teachers' attitude towards learning and teaching, respectively. Many papers investigate the relationships between various building design types and features and students' outcomes (Earthman, 2002, 2004; Higgins et al., 2005; Lemasters, 1997; Schneider, 2002, Buckley et al., 2004). For example, Buckley et al. (2004) suggests that the buildings' shape affects the learning outcomes. As another example, Uline and Tschannen-Moran (2008) find that building age, climate control, indoor air quality, lighting, acoustical control, design classifications, and overall impression are key factors. While these studies make relationships between the level of safety and students achievements, they rarely provide detailed information of perceived safety from students' points of view in the corners and other interior spaces of the educational buildings. Also, mapping the perceived safety for better identification of problematic areas within universities has remained scarce.

ID	Variable	References
SAF	The level of safety in my study place	[26, 27]
PVC	The level of privacy in my study space	[28, 29]
SPS	Feel as safe in an enclosed more private study place	[30, 26]
SRV	You feel if your workspace wasn't monitored by surveillance cameras	[31, 32]
BUR	Bollards potentially lowering the threat of unsafe reactions	[33]
VAS	Access influence, e.g. visibility, accessibility, or safety reasons	[34]
COA	affect your choice of access/circulation point	[35]
BLA	Building layout and architecture	[36]
CRA	Card readers/swipe card access	[37, 38]
ASO	Awareness and availability of the security office who monitor the security camera footage	[39]
AWH	Awareness and availability of help points	[40]

Table 1.
A summary of key variables for conceptualization, Shirowzhan, S 2018.

3. Research methodology

This paper is based on an empirical study on two selected educational buildings. A series of semi-structured questionnaires were designed based on the literature. The questionnaires assisted the researchers to translate the information given by the participants into maps and to evaluate the spaces at two relative local or global levels considering other spaces around the selected areas. A group of participants from each building was interviewed, and the results analysed. A comparison method was chosen to compare two selected educational building cases. The Red Centre and the Tyree Building are situated on the UNSW campus in Kensington, Sydney (See **Figure 2**). Both of these buildings allow data to be collated regarding safety, security, and defence at larger scale due to the size of each building. The buildings themselves are open to the public during the day (no swipe access at main entrances and to public parts at each level), and the boundaries are large glass facades on the ground floor. What protects these glass facades from a potential car/truck is a set of stairs between the University Mall and the interiors. The survey enables to make distinctions between both buildings.

As the appreciation of perception of safety on a scale from 1 to 5 is different for each person, we asked the students to compare one location with another. The information about the differences of perception of safety from one location to another is more accurate than the absolute value itself for one location.

The comments added by the students in the semi-structured sections of the survey enable to appreciate the level of anxiety or well-being of the student better: two students defining the level of safety 3/5 might not have the same level of anxiety. The information in the textbox aims to highlight these differences.

To get a better understanding of the level of safety ranked by the students for the entries of the two buildings, we visualised the average perceived safety level for each entry in ArcGIS and for a better communication with users, and to enhance accessibility to the data, we visualised the GIS layer in Google Earth. To map these ranks, we considered a range of 5 to 1 for mapping feeling of safety where 5 demonstrates feeling of distressed using the entry and 1 reveals feeling totally safe using the location as chosen entry.

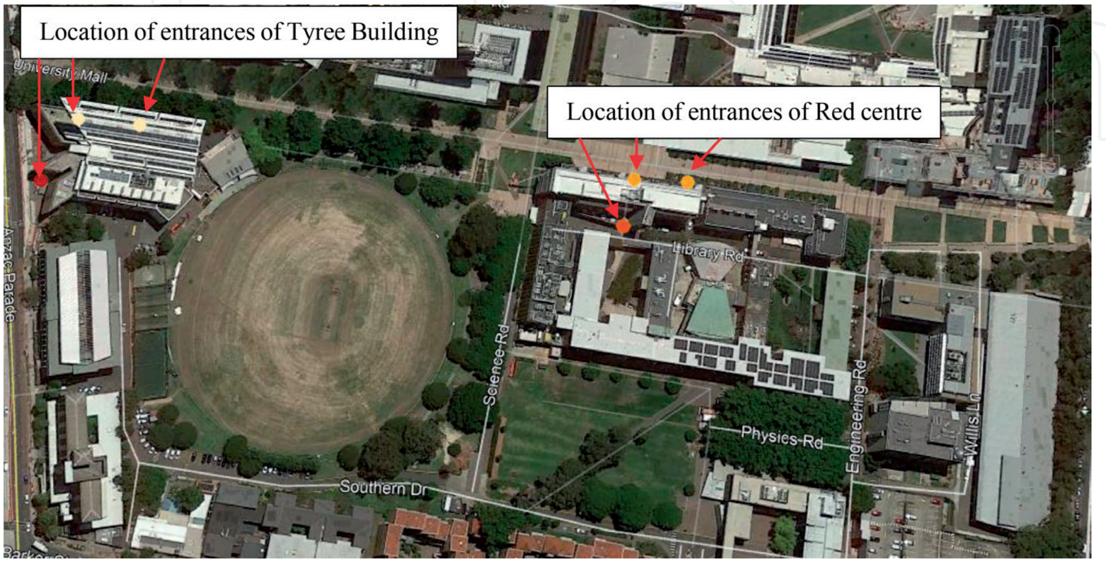

Figure 2.
Red centre and Tyree building at UNSW and the studied entrances in this research.

4. Findings and discussion

Figures 3 and **4** show the feeling of unsafety, for Red Centre and Tyree Buildings entries in different day and night times.

Figures 3 and **4** show the average for each entry gate at different time. **Figure 4** shows that students perceptions in terms of safety for entry 3 (Tyree) are always the same, while entry 1 and 2 may not be safe sometime. Similarly, the same feeling at night time where some lighting facilities are available in front of the case building.

Figure 5 also shows that case 1 has received consistent scores which are average and high. However, the second case entries do not allow students to have a consistent safe feeling at different times, and they may need to change their choices of paths and entries. Based on the evaluation and the available data, the risk map was created indicating the main spots. Average level of safety is demonstrated in different colours in a map created in ArcGIS. The layer is exported into Google Earth, and as can be seen in **Figure 6**, the values of average safety for each entry can be seen and compared. Indeed, this kind of mapping can be used for identification of the problematic areas. In addition, it could be used as a safety base map for the security teams to enhance intervention activities or monitoring facilities for the entries identified to have lower levels of safety.

The facade design was a consistent comment across a number of the students also, suggesting that glass or transparent facades lead to more secure buildings/increased feelings of security. The entrances/exits and circulation were also mentioned in responses from students, suggesting that the design of these has a major impact on the safety of these buildings (particularly in the RC which has a single main entrance/exit point).

The Tyree Building has greater variation across the locations, with Location 03 (from back of building) generally regarded as the least safe option, particularly at night, and Location 02 (from University Mall) regarded as the safest at both times of day. Location 03 is regarded as least safe.

In terms of design we investigated that in Question 9f: Do you think the building layout and architecture (accesses, evaluation of facades, and close surroundings up to 200 meters) have an impact on the level of criminal acts and their nature? The interviewers state that: *The configuration of spaces manipulates places for the human condition and consciousness to use it for their benefits. Criminals acts are not the only factor.*" And also "*the RC has a clear facade and so is quite open. There is also essentially 1 entrance as well.*" Or another participant clarifies that "*the facade of the Red Centre building for the exhibition space and mezzanine are very visible so this may discourage criminal activity; however, the upper floors consist of long corridors and closed off areas may allow for more criminal activity. The concentration of major circulation routes and inefficiency of emergency exits may also encourage this type of activity.*" And finally, "*more advanced designs on facades makes building appear more safe and secure.*"

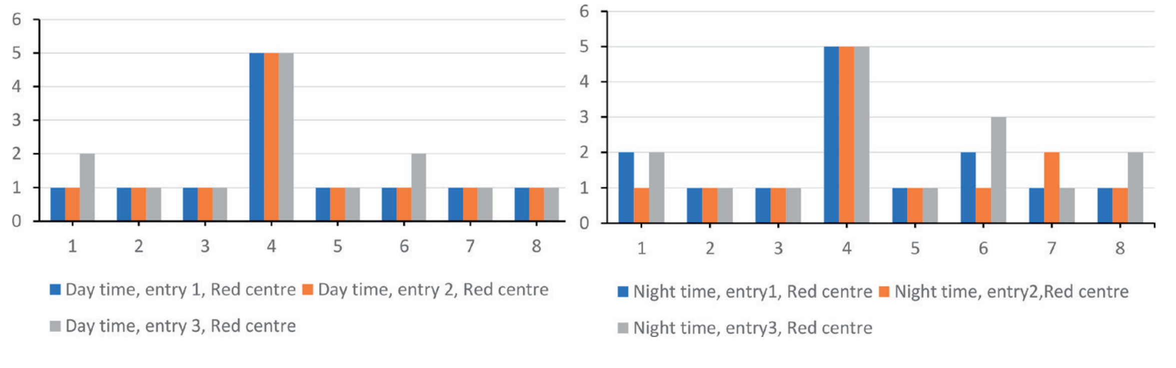

Figure 3.
Day and night time feeling of unsafety for red centre building.

DOI: http://dx.doi.org/10.5772/intechopen.89752

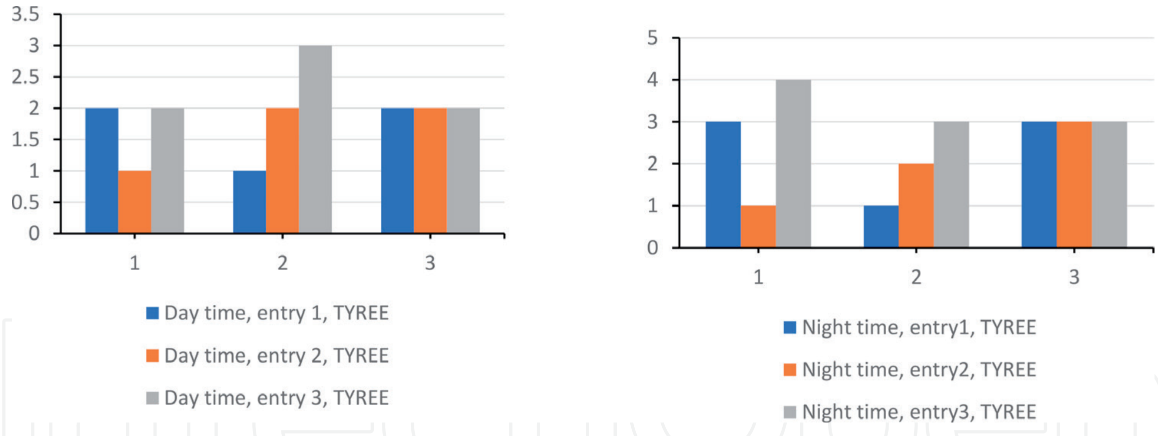

Figure 4.
Day and night time feeling of unsafety for entrances of TYREE building.

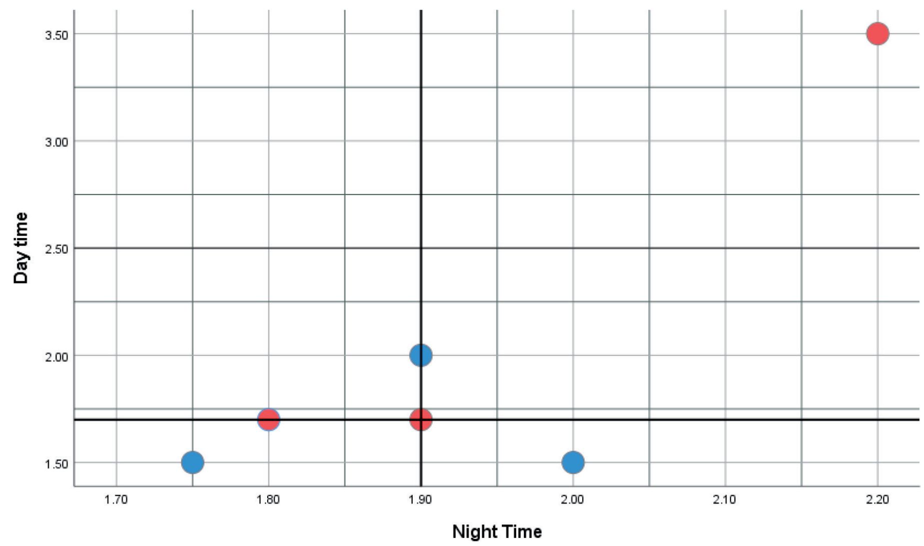

Figure 5.
The average score for each entry gate at night and daytime. Note to figure: Red refers to RC (case building 1) and Blue refers to TB (case building 2). The RC received scores above the median. The TB has received totally different scores for each entry.

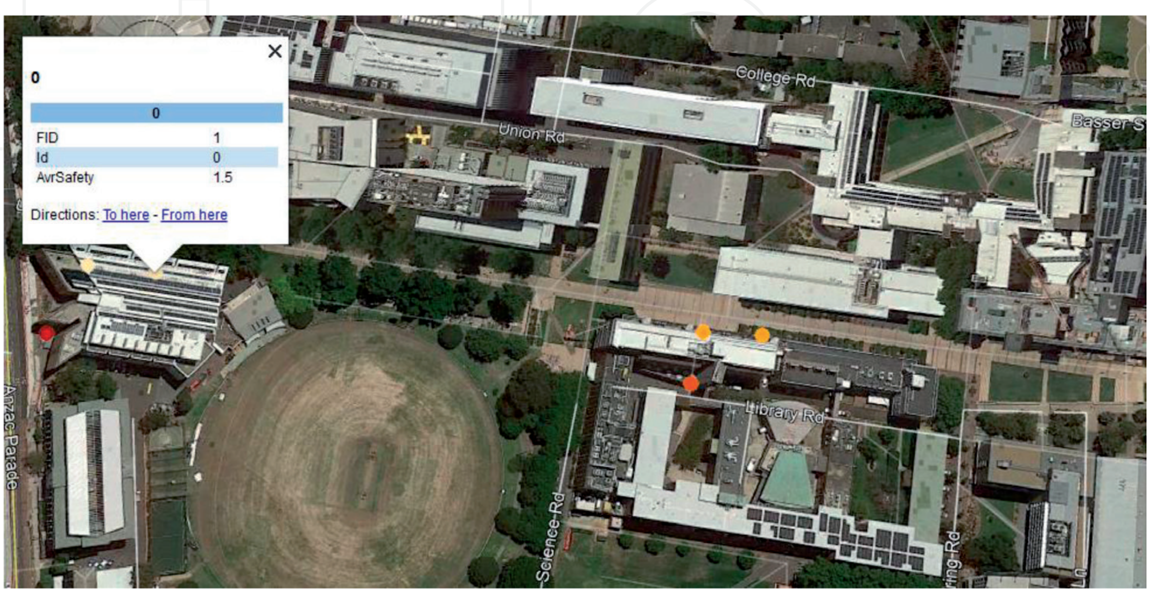

Figure 6.
Demonstration of the rate for a feeling of safety (AvrSafety value in the demonstrated attribute table on the map) for entry 1 of TYREE building.

5. Conclusion and further research

This study aimed to develop a novel method for evaluating and demonstrating risk spots in an educational campus using geographical information systems. The study addressed the following key questions: Which student feels less safe than others, which entry is reported unsafe, and how is daytime safety perceived differently than night time safety? The results show that the Red Centre building is generally regarded as safer than the Tyree Building, during both daytime and night. There are no major differences across both sites during the day; however, the major differences occur for the night rating. Findings indicate that students feel less safe working in the building than the RC work zones. It might be due to the proximity of the TB to the main road (Anzac Parade) and main walkways. One side of the TB is in line with the main road.

Across the two locations, the perception of safety in the RC is consistent during both day and night; however, it was regarded to be slightly safer inside than external location. Across responses to the RC, students either responded with 1 or 5 (extremes of safety or danger), with no responses landing in the middle; it suggests extreme feelings of comfortability on campus or the opposite. Location 01 regarded as most safe, and Location 03 regarded as least safe.

By comparing the results for the two buildings, it is suggested that the openness of buildings is valued by users to feel safe. Glass facades, when designed with safety glass, have a positive impact on the feeling of safety. Safety of university buildings can be achieved through access control coupled with the maintenance of visual links between interior and exterior of the building, i.e. symbolic openness.

The tools developed for this research enable to assist designers and stakeholders in the planning of university buildings. Safety-oriented design, based on the two main strategies of enclosing and layering, can be developed by stakeholders by considering the existing and future users' feeling of safety. Design solutions coupling feeling of safety and architectural quality can be identified and then developed and reused in future projects.

Author details

Sara Shirowzhan, Laurence Kimmel, Mohammad Mojtahedi*, Samad Sepasgozar and Jack Peacock
Faculty of Built Environment, University of New South Wales, Sydney, Australia

*Address all correspondence to: m.mojtahedi@unsw.edu.ua

References

[1] Atlas RI. Understanding CPTED and situational crime prevention. In: 21st Century Security and CPTED. Boca Raton, Florida, USA: Auerbach Publications; 2008

[2] Isdr U. Global assessment report on disaster risk reduction. In: United Nations International Strategy for Disaster Reduction (UN ISDR), Geneva, Switzerland. ISBN/ISSN: 980852698. 2009. p. 207

[3] Huq S, Kovats S, Reid H, Satterthwaite D. Reducing Risks to Cities from Disasters and Climate Change. London, England: SAGE Publications Sage UK; 2007

[4] Reduction ISFD. Living with Risk: A Global Review of Disaster Reduction Initiatives. United Nations Publications; 2004

[5] Kelman I, Gaillard JC, Mercer J. Climate change's role in disaster risk reduction's future: Beyond vulnerability and resilience. International Journal of Disaster Risk Science. 2015;**6**(1):21-27

[6] Australia-New Zealand Counter-Terrorism Committee (ANZCTC). Guidelines for Crowded Places. ANZCTC; 2017a

[7] Homeland Security. FEMA 426 Reference Manual to Mitigate Potential Terrorist Attacks against Buildings. Washington DC: US Department of Homeland Security; 2011

[8] Homeland Security. FEMA 430 Site and Urban Design for Security. Washington DC: US Department of Homeland Security; 2007

[9] HM Government. Crowded Places: The Planning System and Counter-Terrorism. London: HM Government; 2012

[10] HM Government. Protecting Crowded Places: Design and Technical Issues. London: HM Government; 2014

[11] RIBA. RIBA Guidance on Designing for Counter Terrorism. London: RIBA; 2010

[12] Nadel BA. Building Security: Handbook for Architectural Planning and Design. New York City, United States: McGraw-Hill Professional; 2002

[13] Paradis R, Tran B. Whole building design guide: Balancing security/safety and sustainability. USA: National Institute of Building Sciences; 2007

[14] Division of School Support North Carolina. Design of Schools to Prevent Violent Attack. Raleigh, NC: Division of School Support; 2008

[15] Australia-New Zealand Counter-Terrorism Committee (ANZCTC). Crowded Places Self-Assessment Tool. ANZCTC; 2017b

[16] Demkin J. Security Planning and Design: A Guide for Architects and Building Design Professionals. Republished. Michigan, United States: John Wiley and Sons; 2003

[17] Ferreira J, João P, Martins J. GIS for crime analysis-geography for predictive models. The Electronic Journal Information Systems Evaluation. Portugal; 2012:**15**(1)

[18] Santos RB. Crime Analysis with Crime Mapping. California, USA: Sage Publications; 2016

[19] Shafique I, Zahra SA, Farid T, Sharif M. Role of GIS in crime mapping and analysis. Sukkur IBA Journal of Computing and Mathematical Sciences. Pakistan. 2017;**1**:39-47

[20] Sheikh J, Shafique I, Sharif M, Zahra SA, Farid T. IST: Role of GIS

in crime mapping and analysis. Communication technologies (Com Tech). In: International Conference on, 2017. IEEE; 2017. pp. 126-131

[21] Chainey S, Tompson L. Crime Mapping Case Studies: Practice and Research. New Jersey, USA: John Wiley and Sons; 2008

[22] Wilson R, Smith K. What is applied geography for the study of crime and public safety. Geography and Public Safety. 2008;**1**:1-3

[23] Johnson C. Crime Mapping and Analysis Using GIS. Geomatics Conference on Geomatics in Electronic Governance. Tallin, Estonia; January; 2000

[24] Shirowzhan S, Lim S, Trinder J. Enhanced autocorrelation-based algorithms for filtering airborne Lidar data over urban areas. Journal of Surveying Engineering. 2016;**142**:04015008

[25] Shirowzhan S, Sepasgozar SME, Zaini I, Wang C. An Integrated GIS and Wi-Fi Based Locating System for Improving Construction Labor Communications, International Symposium on Automation and Robotics in Construction; 2017. pp. 1052-1059

[26] Neal A, Griffin MA. A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and group levels. Journal of Applied Psychology. 2006;**91**:946

[27] Bosworth K, Ford L, Hernandaz D. School climate factors contributing to student and faculty perceptions of safety in select Arizona schools. Journal of School Health. USA. 2011;**81**:194-201

[28] Sundstrom E, Herbert RK, Brown DW. Privacy and communication in an open-plan office: A case study. Environment and Behavior. 1982;**14**:379-392

[29] Dowling R, Atkinson R, Mcguirk P. Privatism, privatisation and social distinction in master-planned residential estates. Australia: Urban Policy and Research. 2010;**28**:391-410

[30] Loukaitou-Sideris A. Safe on the move: The importance of the built environment. In: The Urban Fabric of Crime and Fear. Springer; 2011

[31] Räty TD. Survey on contemporary remote surveillance systems for public safety. IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews). 2010;**40**:493-515

[32] Wang X. Intelligent multi-camera video surveillance: A review. Pattern Recognition Letters. 2013;**34**:3-19

[33] Rothrock SE. Antiterrorism Design and Public Safety: Reconciling CPTED with the Post-9/11 City. Massachusetts Institute of Technology; 2010

[34] Basile O, Persia L, Usami DS. A methodology to assess pedestrian crossing safety. European Transport Research Review. 2010;**2**:129-137

[35] Lee JM. Automated Checking of Building Requirements on Circulation over a Range of Design Phases. Georgia Institute of Technology; 2010

[36] Kobes M, Helsloot I, De Vries B, Post JG. Building safety and human behaviour in fire: A literature review. Fire Safety Journal. 2010;**45**:1-11

[37] SS-SIS-RP A. Equipment and Technology for Public Transit. USA: American Public Transportation Association; 2013

[38] Richardson C. Working Alone: Protecting and Building Solidarity in the Workplace of the Future. Boston, USA: Labor Resource Center Publications; 2010

[39] Keval H, Sasse MA. "Not the usual suspects": A study of factors reducing the effectiveness of CCTV. Security Journal. 2010;**23**:134-154

[40] Jones MK. Interactive Personal Surveillance and Security (IPSS) System. Google Patents; 2013