SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Integration of Building Information Modelling (BIM) in Third-Generation Crime Prevention through Environmental Design (CPTED)

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ARTICLE INFO

Article history:
Received 4 July 2023
Received in revised form 23 September 2023
Accepted 2 October 2023
Available online 24 October 2023

Keywords:
Building Information Modelling; Third Generation; CPTED; Crime Prevention; Digital Technologies

ABSTRACT

The awareness level of residents to prevent crime is increasing while the characteristics of the physical environment and atmosphere within the residential areas have been utilized to discourage crime. Crime Prevention through Environmental Design (CPTED) as an effective crime prevention strategy has been introduced since 1971 where it evolved from the first-generation to second-generation after including intangible components into the practices. Currently, the emergence of digital technologies such as Building Information Modelling (BIM) has started to gain more attention from academicians and practitioners. The features in BIM such as simulation, visualizing and estimating should be utilized to enhance CPTED effectiveness in preventing crime which will form the fundamental of third-generation CPTED. This study intended to explore the potential to integrate BIM into existing CPTED to develop a third-generation of CPTED. Therefore, this study has reviewed the journal articles pertinent to the BIM application in CPTED which elaborate the potential of BIM to be used practically to provide new concept of third-generation CPTED which embracing digital technology. This study found the potential of BIM to integrate with four tangible principles (surveillance, access control, territoriality and target hardening) and two intangible principles (sense of community, and management and maintenance) have been discussed. All existing principles can be integrated with BIM to further enhance their effectiveness but there are some conflicts found between the principles practiced in CPTED. This study has provided a comprehensive overview of the integration of BIM to CPTED practitioners for the development of third-generation CPTED in future research.

1. Introduction

Urban planners and designers are always considering the issues of crime and the fear of crime among residentials when they are managing the urban spaces [1]. This is due to the significant increase of human population in the world which has encourage rapid urbanization, especially in the developing countries such as Malaysia. The crime issues in urban areas will compromise and undermine the efforts towards developing sustainable cities significantly as crime will cause

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https://doi.org/10.37934/araset.32.3.438450

significant costs to the society, both in monetary and social terms [1]. Among crime, properties crime is one of the most commonly experienced and feared by public which affecting the society and residents' perception of safety and amenity [2]. Furthermore, properties crime will affect the quality of life of residents and result in the withdrawal from the current neighbourhood or implement more security which considered as overfortification of properties [2].

Building Information Modelling (BIM) is starting to gain popularity in the housing industry. Therefore, BIM can be used as a new tool to enable additional reviews on the CPTED components such as territoriality, target hardening, access control, surveillance, sense of community, image maintenance and adoption of technologies in the design of existing and new buildings [1]. CPTED has been defined as "the proper design and effective use of the built environment can lead to a reduction in the fear and incidence of crime, and an improvement in the quality of life" [1, 3]. BIM is not limited to software only as it can be a product, method, or a tool/software. Therefore, BIM can also be understood as "the use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions" [4].

Residential crime has a long and diverse history of research. This paper has the intention to contribute to the existing body of knowledge by exploring the potential use of BIM visualization in the implementation of traditional CPTED which can enlarge the understanding of housing design, crime risk assessment and components in third generation CPTED. This paper uses residential crime as an example on how BIM could enhance the effectiveness of built environment and third generation CPTED practices in the adoption of crime prevention strategies in residential areas as this paper believes BIM has the potential use in exploring all types of properties crime in residential areas and in enhancing the implementation of third generation CPTED to deter properties crime.

2. Literature Review

The existing literature on the residential crime is extensive and any attempt to review these literatures is beyond the capability of researchers [1]. Thus, this paper intends to review only latest and pertinent articles in the potential of BIM adoption in the implementation of third generation CPTED in residential areas. The integration of BIM visualization function in third generation CPTED can specifically contribute to the existing body of knowledge to elicit perceptions of properties crime, housing design and security measures. An overview of the integration of BIM visualization and simulation functions into CPTED in the study of residential crime is provided below as the discussion of more recent visualization and simulation methods. Basically, this paper discusses the potential contribution of BIM to the study of residential crime and in improving the implementation of third generation CPTED in the development assessments.

2.1 What is BIM?

BIM has potential in bringing a paradigm shift to the existing Architecture, Engineering and Construction (AEC) industry in terms of building design, construction activities and building operation. BIM is a new emerging technology which can be utilized by building design software. This technology can portray building elements with 3D objects with many associated items rather than 2D lines and shapes which typically shown in traditional 2D Computer Aided Design (CAD) drawings [1]. For example, Wang, et al. [5] has emphasized a wall in BIM can be represented with a wall object associated with items such as structural design, material, acoustic, fire resistance, time and resources needed, and cost properties rather than abstract lines, shapes and spatial coordinates that shown in 2D drawings. Furthermore, BIM can be further developed by adding several additional non-spatial

"parametric" properties of objects as additional "dimensions" with the first three spatial dimensions of the model are length, width, and height. The fourth dimension (4D) is the temporal characteristic of the model which shows the time frame needed to complete the construction activities while the fifth dimension (5D) is the resources or cost needed for the construction task. Facilities management can be added as the sixth dimension (6D) which could help the management and maintenance works of a building. The number of subsequent dimensions can be further added according to the construction project's interest such as safety and health and sustainability. Moreover, geographical data sources such as local spatial data (terrain) can be considered and integrated into BIM's model to further improve the accuracy [6].

BIM is defined as "a modelling technology and associated set of processes to produce, communicate and analyse building models" by Eastman, *et al*., [7]. The "building models" in BIM means digital representations of building components that contain specifications such as geometry, functional and behavioural attributes and parametric rules [7]. BIM can do more than just buildings as it is a process that enables efficient and quality design, operation and maintenance of a structure and simulation of a proposed proposal [8]. BIM has the capabilities to do simulation by using 3D visualization but the current visualization capabilities offer by BIM are limited to a certain number of areas [9]. Furthermore, Ceccato, et al. [8] also said that there is no research that use BIM for visualizing and analysing the criminal occurrences inside buildings.

Succar [10] has defined BIM as a "methodology to manage the essential building design and project data in digital format throughout the building's lifecycle". The development of BIM has become the main driver in promoting 3D visualization and detailing, cost reduction, speeding-up the delivery time, highlighting the conflicts or clashes, providing opportunities for value engineering and reducing waste in every phase of construction project. BIM is the outcome of merging information content, geometry, site surveys and functional data about performance, materials and quantities. This shows BIM involves dynamic data management of the information generated and used during the operation of buildings which further substantiate BIM is not a software tool solely. BIM has driven the formalization of the traditional document management process into a digital-based practice of construction and management process and facilities management in post-construction stage [11].

In addition, the function of BIM is significant as a structured model and a detailed representation of physical building which can help in the automation of construction tasks and acting as a platform to facilitate the sharing of information among project stakeholders. Initially, BIM emerged as a framework which can enhance the documenting processes and building construction project management but due to the huge details and size of the data contained within BIM models, more functions have been developed to improve the efficiently and productivity of BIM [1].

2.2 Crime Prevention through Environmental Design

Georgiadou [12] said that housing industry is a priority research area. The housing industry has the longest lifecycle, the worst environmental performance and the least available funds to apply complicated design methods [13]. Furthermore, property developers are not proactive in the housing industry as they are only motivated by the profits and legal aspects within the construction period. The efforts of property developers in post-construction stage are possibly done at the cost of resilience and due to the sustainability requirement from the authorities.

Moreover, the increase of population has caused rapid urbanization of cities which further brought massive development of housing. This has led to the increase in the crime rate and the fear of crime among residents in urban areas [1]. The raise of crime rate has become the primary concern of authorities who plan and develop urban areas as the security issues in cities have trigger the

concern of the public on their security level in residential areas [2]. In this case, many results show that the crime occurrence is due to the physical built environment characteristics but not the offender personal factors [2]. Therefore, several physical factors of the built environment have been proved to affect the crime rate and security level in residential areas such as territoriality, surveillance, access control, target hardening, and maintenance and management.

CPTED, defensible space and Broken Windows theory have been used to investigate the relationship between the built environment and crime rate in residential areas. Basically, all these approaches are related to the implementation of crime prevention strategies that rely on the built environment. Broken Windows theory is emphasizing on the image maintenance by the residential management team where the residential areas which are well-maintained will show the belongings of owner and a symbolic distinction between the public and private area The distinction will form the fundamental of territoriality [14]. On the other hand, defensible space's concept focuses on the sense of belongings among residents where residents must protect the residential area within the territory which is fenced by walls [2]. CPTED is the advance version of crime prevention strategies which consists of several tangible and intangible components such as territoriality, surveillance, access control, target hardening, sense of community and image maintenance. First-generation CPTED was introduced by Jeffery [15] who think that physical built environment will affect the crime rate where the crime prevention strategies can be integrated into the built environment.

The first-generation CPTED introduced by Jeffery [15] is emphasizing on the physical built environment solely but second-generation CPTED tried to integrate social aspects such as social ecology, neighbourhood planning and collective efficacy into the physical built environment [16]. The integration of social aspects into physical environments will improve the effectiveness of CPTED in reducing crime rate in residential areas significantly. Moreover, the combination of the physical and social attributes in CPTED form the basis of third-generation CPTED which emphasizes on the cognitive, behavioural and environmental sciences such as sustainability, social information processing and satisfaction on the surroundings built environment [2]. On the other hand, the development of third-generation CPTED which consider the integration of digital technologies has gained more attention. This is because people are seeking for the criteria in third-generation CPTED that seeking for connectedness, satisfaction from achieving goal and the capability to contribute to the society [17]. From the above statement, third-generation CPTED is not a sole crime prevention strategy but works as a motivation reinforcement strategy to reinforce pro-social behaviours which proposed by first- and second-generation CPTED to improve the quality of life and livability [17].

In the early stage of third-generation CPTED, the liveability in the urban areas is focused where urban informatics are used to help residents to understand and respond to the city better, enhancing sense of community among residents and encourage local participation in the sustainable activities which can further prevent crime. In the early generation of CPTED, community safety and liveability are often being the priority of the crime prevention strategies but three complementary aspects including economic, environmental and social performance are the core of third-generation CPTED as these subjects will directly influence the liveability and quality of life of residents [18].

Moreover, the integration of digital technologies into third-generation CPTED such as BIM, Global Positioning Systems (GPS), Internet of Things (IoTs) and Radio Frequency Identification (RFID) can further improve the effectiveness of the approach. BIM can be used to present the crime prevention idea by interpreting the designs, creating diagrams, monitoring the surrounding, planning schedules and maintaining facilities [19]. This can be understood as the simulation of a completed neighbourhood. The simulation function of BIM in the operational stage can be used by planners and designers as crime prediction tool to determine the final design for the construction project. Planners and designers can use BIM as a tool to carry out simulation to identify potential weaknesses in the

design such as blind spots which can cause crime to happen. This will help to reduce the error in the design. This substantiates the effectiveness and efficiency of CPTED can be better predicted and crime rate can be reduced with the implementation of 3D/4D/5D BIM visualization technology where non-parametric dimensions such as cost (4D) and (time) are added into the BIM consideration. Although the integration of BIM visualization into CPTED crime prevention method can be effective, the studies in this area are still very limited. The integration of BIM visualization technology into third generation CPTED can be used in existing buildings as the combination of BIM and image recognition can be used to improve the security features by conducting a photographic analysis that merge and process the 3D image from surroundings into a BIM model. Practitioners can take pictures surrounding the existing buildings and utilize BIM software to find suitable spots to install CCTV which can increase the surveillance coverage area. The combination of both techniques will help planners and designers to predict the possible problems and thus improve the security features and level after evaluating the potential incidents. This will help the parties to produce practical design.

Conditional crime prevention consists of three main components which are the mechanical, organizational, and natural components. Mechanical equipment such as CCTV and alarm are the tools under mechanical components which have been utilized as surveillance and alarming system within the residential area. Human activities such as security teams, organization structure of the residential and security guards patrolling in the residential area are associated by the organizational components. Natural spatial aspect such as space design, orientation of landscape and circulation within the residential area are the natural components that can help to prevent crime [20]. These components can be further analyzed under the six main parts which consist of surveillance, territoriality, target hardening, access control, sense of community and image maintenance. Since BIM is a powerful tool in enhancing design which can prevent crime, the application of BIM will be discussed together with these main parts.

2.2.1 Surveillance

Surveillance refers to the activity of watching and monitoring neighborhood areas for suspicious activities and the presence of strangers. Basically, there are two types of surveillance which are the natural surveillance (informal) and mechanical surveillance (formal) [21]. The natural surveillance is formed by resident's self-surveillance opportunities which facilitated by openings such as windows and neighborhood activities [22]. Blind spots such as the corners of the neighborhood provide a space for the offenders to hide and ambush the residents [23]. Therefore, the design, architecture, urban design and planning of a built environment will affect the effectiveness of surveillance which influence the capability of residents to reduce crime. This is derived from the idea which assumes if offenders think they can be seen easily, they will stop committing crime as this will increase the possibility for intervention, apprehension, and prosecution. Moreover, natural surveillance also relies heavily on street lighting aspect which will affect the formal surveillance [23-25]. BIM could be used to provide a better design which allows more natural surveillance through openings such as windows and doors where residents can always watch the surroundings area.

Since lighting aspect is vital, the installation of street lighting will affect the effectiveness of natural surveillance [26]. Nighttime will be the most vulnerable time where offenders have more opportunities to commit crimes and the fear of crimes among residents will increase significantly. In addition, most of the currently installed streetlights do not have the right illuminance which caused certain spots in the residential area to be dim or dark at night. This substantiates the importance of having the right level of light illuminance to improve the visibility of residents/pedestrians while walking around the neighborhood area at night. However, high illuminance level will consume more

electrical energy, thus, Connected Security Lighting System (CSLS) can be used as it detects residents/pedestrians' movement and automatically increase the street light illuminance which can save electrical energy consumption and reduce the fear of crime of residents Cho, et al. [25]. Therefore, BIM could be utilized in the simulation and visualization to test the illuminance level before the final decision is finalized.

On the other hand, mechanical surveillance utilizes street lighting, CCTV, and security guards to prevent crime. Mechanical surveillance focuses on patrolling activities which can survey the neighborhood area for suspicious people and activities [23]. Security guards are the most common practice in mechanical surveillance, but the residential area size is getting bigger, especially in cities. Therefore, CCTVs have been utilized to monitor every single corner in the residential area. However, this has indirectly increased the workload of security guards who stay in the control room and causing them to have a hard time focusing on the CCTV due to the massive number of monitors to focus on [23]. The performance of mechanical surveillance could be further improved through the implementation of BIM visualization and simulation where the positions of CCTVs could be planned better which ultimately can increase the focus on security guards while reducing the massive number of CCTVs. This can be achieved as BIM could be used to simulate and find the best spots in the building to install CCTVs which can cover the widest sight. Eventually, this can reduce the number of CCTVs installed in the building.

On the other hand, geographical juxtaposition is related to the surveillance where it refers to the remoteness of an area from the central where majority of activities are conducted in the residential area [27]. Certain spots in the residential area are the weak point which can attract crimes due to the lack of light, blind spot from the surveillance and lesser human activities. These areas will be wasted as people will avoid from approaching these spots [23]. Most of the parents will allow their children to play within the residential area but children will be prohibited to go near the spots which have higher crime occurrence rate due to the "stranger danger" mindset [28]. Sugino and Arima [29] studied the CPTED spatial vulnerability targeting arson and found the arson crime spot is normally located far away from arterial roads and surrounded by multiple buildings with various purposes. These spots usually have void spaces or blind spots which encourage the arsonist to run away. This shows that geographical juxtaposition as one of the components in CPTED which emphasized on the locations nearer to a crime generating facility will be impacted to a great degree than those farther away [27]. As BIM could show the orientation of buildings in 3D which could ease the understanding of stakeholders, BIM should be utilized as a visualization or simulation tool to reduce the blind spot areas and detect the areas that are badly lit.

2.2.2 Access control

Access control means controlling the entrance permission to the residential area. This will reduce the offenders' opportunity to enter the residential area by limiting the entrance of outsiders in the main road and gate [17, 26, 30]. There are several approaches that can be used in enhancing access control in residential areas such as boom gate, guard house and card access system [26].

Access control will limit the accessibility of offenders where residential areas will be difficult to break in and escape. Therefore, aspects such as escapability and accessible networks within the residential areas should be focused. Escapability refers to the aspects such as having multiple accessible gates or doors which allow offenders to escape from the residential areas. Silva and Li [31] has further substantiated escapability is one of the factors contributing to high crime rate as offenders can use the same method entering the residential area to escape from the crime scene. On the other hand, accessible network which refer to an area that connected by multiple routes or

streets also help offenders to escape easily [26]. This factor is supported by various literature as when a residential area is connected to multiple streets and routes will easily allow the outsiders to access the area from multiple paths from different locations which will cause difficulty in identifying potential offenders [32-35]. The capability of BIM could be optimized in this aspect where the position of entrance and exit could be assigned correctly. Furthermore, the entrance and exit points could be planned better to place these points on the road which can reduce the escapability and accessibility of the offenders.

2.2.3 Territoriality

Territoriality means an area that is designed properly to clearly distinguishing the private and public space [26]. This will promote the sense of ownership among residents which will further ease the efforts to differentiate outsiders and intruders [35]. Normally walls or fences will be installed along the perimeter of the residential area to limit the entrance of outsiders. BIM could play its roles in designing the walls or fences along the perimeter of the residential area to spot the weak points of surveillance such as blind spots to reduce the opportunity for offenders to break through the walls or fences installed along the perimeter.

However, residents might find difficulties in feeling a sense of ownership in their residential area if the residential itself is living by potential criminals. Offenders might socialize with the residents within the neighbourhood area which will affect the effectiveness of territoriality [31]. Therefore, it is imperative to know the majority of the residents within the neighbourhood to improve the feeling of safety, which will further enhance the sense of ownership. This social aspect also has been emphasized by second-generation CPTED [16].

2.2.4 Target hardening

Target hardening refers to the enhancement of protection tool such as implementing items that can be the obstacles or barricades to increase the difficulty of offenders to success in committing crime [16]. Target hardening will give a sense of pride and confidence to the residents in defending their homes [36]. These protection tools should be installed in house unit and carpark area as the lack of target hardening installed in carpark area provided more opportunities for thefts to steal the vehicles, especially motorcycles [37]. Although many literature are substantiating the effectiveness of target hardening in reducing crime rate in residential areas but being too confidence in the installed tools can give a false sense of full safety to the residents too [38]. Therefore, the adoption and collaboration of various crime prevention tools is imperative in reducing the crime rate.

Target hardening has been established for a very long period of time which can increase the difficulty of offenders in committing the crime successfully [26]. Target hardening is used to restrict or limit the access of criminals into the premises by using physical barriers such as door and window lock, grill, fences, walls, gates and electronic alarms [21]. However, too much target hardening implementation will create an unfriendly environment where the residents seem like living in a fortress rather than a residential area which promotes the feeling of fear of crime within the community. Furthermore, over adoption of target hardening is in contrast with second-generation CPTED concept which emphasizes on the social aspects as there will be lesser interaction among residents.

Facilities management can be considered as the sixth dimension of BIM could be utilized in this aspect as installed target hardening tools need to be maintained regularly to ensure the installed security features can continues functioning effectively and preventing crime within the residential

area [39]. The BIM with sixth dimension is known as the 6D BIM where it could help to improve the efficiency of the management team in the routine maintenance works. Building management team can utilize BIM in alerting them to carry out particular routine maintenance works in the designated spots to avoid situation where certain spots are overlooked.

2.2.5 Sense of community

Sense of communroutineas activity support which can be achieved through a series of community activities in the residential areas to improve the interaction among residents which can prevent crime [30, 40]. Nowadays, most of the residences come with facilities such as swimming pool, gym, sport courts and park where interesting events can be conducted to attract the residents to visit these areas more often. This will reduce the crime rate as offenders would be less likely to commit crime in these areas due to the higher level of natural surveillance which comes from "eyes on the street". Illegal activities can be seen and monitored easily in these areas [26].

In addition, the role of residential management team should be emphasized to promote the sense of community as facilities within the residence should be maintained well to ensure the provided facilities are functioning properly. The maintained facilities such as decorations and landscaping are portraying sense of ownership to the outsiders and encouraging residents to use these areas to carry out leisure activities [41]. Besides the sense of ownership, the maintained facilities will show territoriality spatial formation which limit the entrance of outsiders which can provoke defensive actions by residents in the event of outsiders trespass the residence by calling the police or neighbours [42].

BIM should be adopted in the design stage to visualize and simulate the provided facilities for leisure activities which can attract the residents to visit these areas frequently. The decorations and landscaping could be designed creatively to attract the residents. Once more residents are attracted to these areas, the level of natural surveillance will be improved significantly and reduce the opportunity for offenders to commit crime directly.

2.2.6 Management and maintenance

Management and maintenance in CPTED focus on the residence image maintenance which originated from Wilson and Kelling [43]'s Broken Window theory [14]. This theory believes if the broken window of a building is not repaired timely, more windows will be broken deliberately and ultimately, criminals will break into the building [14]. This substantiates the importance of residence maintenance where the landscape should be maintained while the rubbish should be cleaned regularly to create a good image and civilization for the potential offenders. Moreover, the environment sanitation, public facilities, lighting system and civilized behavior are also contributing to the prevention of crime as these efforts will further reduce offenders' intention in committing crime in this area.

On the other hand, broken windows theory believes a poorly-maintained residence always convey negative signal to the offenders where this area do not gain attention from residents which will attract crimes [14]. Furthermore, the poorly-maintained residence might be full of rubbish which raise environmental concerns [14]. A poorly maintained residence has been proved to have higher crime rate than a residence with a well-maintained residence due to image maintenance. This is due to the broken facilities, unmaintained landscape and inappropriately disposed rubbish are sending out signals to attract crime into this area. Several studies also revealed that poorly maintained residences portray image as spaces without guarding are more liable to crime activities. Due to the

capability of BIM that could add in non-parametric dimension such as facilities management (6D) into the building model, the routine maintenance, preventive maintenance and periodic maintenance works could be greatly assisted by 6D BIM. The residence image could be maintained by utilizing 6D BIM as the maintenance works would be planned earlier and complete perfectly without the chance to overlook every edge of the building.

3. Discussions

This paper has assessed the potential of BIM-based visualization capabilities in integrating into the implementation of third generation CPTED in residential areas by reviewing existing literature. 2D drawings and paper-based documentation were the primary references for a building to be designed, constructed and managed previously but the invention of 3D BIM method which acts as a shared knowledge platform with the integration of digital models has started to shift this practice into a more efficient method [12]. BIM uses 3D, real-time, dynamic modelling software to increase the collaboration and productivity to maximize building lifecycle value [44]. This is due to the capabilities of BIM model to incorporate digital data on 4D (time/scheduling), 5D (costs/resources), 6D (facilities management) to offer a more effective crime prevention design and strategy which will improve the effectiveness and efficiency of building management team in preventing crime by supervising, operating and maintaining the residential area [45]. The integration of BIM technologies is even more helpful for retrofitting and refurbishing existing projects because these projects have higher risk due to the need of collaboration and integration needed within the project lifecycle compared to new construction projects. However, the integration of BIM into housing sector is still facing huge challenge due to fragmentation and complex stakeholder engagement [12].

CPTED principles could be categorized into six tangible principles (surveillance, access control, territoriality, and target hardening) and two intangible principles (sense of community, and management and maintenance). This study has explored the potential to integrate BIM into these principles. In the tangible CPTED principles, the surveillance focuses on the routine activities theory as offenders can easily commit crime if the area is not monitored [1]. The combination of natural and mechanical surveillance systems will help to prevent crime effectively and diminish the fear of crime among residents. On the other hand, the use of landscape design and proper signages will encourage intended purpose of usage in certain areas which will promote natural surveillance [39].

On the other hand, the capability of BIM could be optimized in access control where the position of entrance and exit could be assigned correctly. Furthermore, the entrance and exit points could be planned better to place these points on the road which can reduce the escapability and accessibility of the offenders. Visualization of the access control could be presented to key stakeholders by using BIM. Next, territoriality concept is effective in reducing crime, but it is contradicted with two other elements in CPTED which are surveillance and accessibility. The main purpose of having territoriality is to ensure residents have lesser fear of crime but if there are multiple access gate and CCTVs installed in the residential area for security purposes, the residents will be more anxious about their safety [23]. Moreover, the territoriality concept also contradicts to the surveillance component in the aspect of having walls or fences installed around the perimeter of the residential area as these walls or fences will block the view of residents and CCTVs which will further reduce the effectiveness of natural and mechanical surveillance practices [23, 36].

The combination of tangible and intangible principles of CPTED can enhance the performance of CPTED concept in reducing and controlling crime rate in residential areas. For example, image maintenance of a residential area can prevent crime from happening inside this area as offenders will feel the maintained residential area is guarded by the residents. A residential area that portrays

a good image is equally important as the installation of security features. Therefore, the combination of management and maintenance, and target hardening will promote a positive image to the outsiders. Moreover, routine maintenance conducted regularly will maintain the installed security features to continues functioning effectively and preventing crime within the residential area [39]. The installed security features which act as target hardening within residential area will cause more difficulties to the offenders in committing crime successfully.

In addition, both tangible principles in CPTED practices can be combined to achieve better outcomes. For example, target hardening can collaborate with the practices in access control such as enhancing the surrounding of the residential area by having access control system, fences, walls and signpost [26]. This combination can further reduce the crime rate as access control is an approach that can reduce the occasions for commission of crime by increasing the risk of getting caught if offenders committing crime in this area [17]. The combination of target hardening and access control can be presented in the form of fencing, walls, automatic lockset and electronic alarm systems that can further prevent property crimes [23]. These physical security features are important in controlling the crime rate, but numerous studies have been conducted and reveal those unsafe residential areas which have higher crime rate are properties with multiple security features.

Basically, CPTED principles rely on three fundamental overlapping strategies which incorporate controlling access, increasing opportunities for surveillance, and promoting a sense of ownership. These strategies will improve the social interaction among residents through physical security features which can reduce the opportunities for crime [46]. CPTED has emphasizes the environmental aspects where built environment has been designed to reduce crime and improve the social aspects such as quality of life which can be seen in diverse aspects such as communities, public transportation and commercial activities [41, 42, 47]. A well-maintained residences promote the sense of ownership where a signal is sent out to outsiders that this area is under monitoring [48]. This is due to the cleanliness of the dwelling and its surrounding areas showing stronger sense of belongings which prevent crime, vandalism and incivilities [49]. A well-maintained residence will give a perception of fewer or no social problems in the vicinity.

4. Conclusions

This paper has discussed the development of third generation CPTED by exploring the potential of integrating BIM. BIM could be utilized for the visualization of the environmental analysis of crime and crime vulnerability. By exploring the CPTED practices and BIM capabilities across a broad range of recent literature, this study found the potential application for the integration of BIM into third generation CPTED, especially in the design stage of the residential development. BIM can be used in several assessments which are pertinent to spatial aspects. The efficiency of different CPTED principles in the proposed design could be tested by using BIM to visualize and simulate their functions. Since BIM is adding more and more non-parametric dimensions into consideration, the integration of BIM into CPTED principles not only reducing crime rate in the residences but also ensuring sustainability of housings which further creating the opportunity to development third generation CPTED. As BIM has high potential to be integrated into CPTED principles implementation, a case study can be conducted as future research to further validate the effectiveness of BIM in assisting crime prevention strategies.

Acknowledgement
This research was funded by School of Housing, Building and Planning, Universiti Sains Malaysia.

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