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Enhancing urban safety through honeycomb housing design: A quantitative analysis of crime prevention

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ABSTRACT

Honeycomb housing is a new design within the category of cluster housing that was inspired by the Prairie House concept created by Frank Lloyd Wright between 1900 and 1901. This design uses a hexagonal pattern to form clusters. It presents an alternative to traditional housing layouts, addressing problems like urban overcrowding, high crime rates, and social unrest. Therefore, this research aims to explore how the design of honeycomb housing can contribute to preventing crime and enhancing the safety of urban communities. This is done by examining aspects such as natural surveillance, controlled access, clear boundaries, upkeep, and management. The research adopts a quantitative approach, utilizing surveys completed by 168 heads of households in honeycomb housing, both owners and renters, selected through cluster sampling in Nong Chik Heights, Johor Bahru. The analysis of the data involved descriptive and inferential statistics, including means and standard deviations, frequencies and percentages, and correlation analysis. The findings indicate a positive link between the design of honeycomb housing and crime prevention in urban areas, supported by the principle of maintaining vigilance over public spaces to ensure community safety, tranquility, and protection against external threats.

1. Introduction

Honeycomb housing is a modern design in the cluster housing category that originates from the Prairie House idea by Frank Lloyd Wright in 1900-1901 to the Usonian House design in 1932 in the United States (Betsky et al., 2021; Hoffmann, 1995; Sergeant, 1984; Stevenson, 2019; Marzano et al., 2023). Honeycomb housing with the Usonian Hexagonal design is worked through a hexagonal geometric tessellation method like a beehive (Bajunid and Ghazali, 2012). It allows 1 acre of land to build 14 units of honeycomb houses (subject to the type of house, with an estimate of 70 people per acre). With that, the number of house units in a neighborhood courtyard contains 5 to 16 house units. Next, this courtyard neighborhood is grouped into a cul-de-sac community with 42 house units. Later, this cul-de-sac community will merge, forming a larger neighborhood of 300 house units. It shows that the neighborhood is formed from interconnected units as if forming a beehive. This layout is very unique because each house unit has a wide frontage. So, it looks like a house on the corner (corner lot) because each precinct that uses the hexagonal grid cul-de-sac seems to resemble the structure of a beehive (Bajunid and Ghazali, 2012). Honeycomb housing consists of a single house, duplex (joint of 2 units), triplex (joint of 3 units), quadruplex (joint of 4 units) and sextuplex (joint of 6 units).

Thus, this hexagonal tessellation allows houses to be arranged in a cul-de-sac with an open area in the middle to create a neighborhood courtyard. Indirectly, all the houses in the area will face the open garden like sitting around a table. Each neighborhood courtyard will be connected to a distributor road as a Y intersection (Ghazali et al., 2005). Next, the grouping of this cluster house undergoes a form repetition process (honeycomb tessellation) until it creates a perfect interlocking geometry due to the hexagon grid (Abidin, 2012; Bajunid and Ghazali, 2012; Klinkowitz, 2014). This hexagonal shape is considered practical in housing

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development because this layout allows houses to be arranged in small cul-de-sacs aimed at promoting familiarity in neighborhood groups, avoiding the direct flow of traffic and speed in residential areas while forming a safe neighborhood through one road to facilitate the process of identifying foreigners, avoid public disturbances and prevent criminal activities (Marzano et al. 2023; Bajunid et al., 2017; Jacobs, 1992).

The string, the honeycomb housing found in Nong Chik Heights, Johor Bahru, is the first success in Malaysia that organizes cluster housing in hexagonal honeycomb grouping (Bajunid and Ghazali, 2012) used as a case study in this research. The study examines how honeycomb layout design can prevent crime through an 'eyes on the street' approach in maintaining the safety of urban neighborhoods, such as natural surveillance, natural access control, boundary clarity, maintenance, and management (Cozens, 2013; Jacobs, 1992; Kanigel, 2017; Laurence, 2016; Shamsuddin and Hussin, 2013). All of the above crime prevention elements are strongly emphasized in the National Housing Policy (DRN) (2018-2025), which aims to generate sustainable, livable habitats with quality and cohesive neighborhoods that will result in close-knit communities and harmonious and safe settlements in line with the slogan "home the quality of the people's hopes" (Masram and Misnan, 2019). At the same time, it can improve the Happiness Index of Residential Areas (MURNI nets) and the Live Ability Index of Malaysia (IDAM), which is in line with the UN goals in SDG11: Urban and Community Sustainability towards the Shared Prosperity Vision 2030 (WBG, 2021; Zin, 2014; Zubi, 2018).

2. Materials and methods

This quantitative study uses a questionnaire method on 168 samples involving all the heads of honeycomb households, whether owners or tenants, through a cluster sampling technique in Nong Chik Heights, Johor Bahru. The questionnaire used obtained a high and satisfactory Cronbach's alpha result (0.90). The questionnaire is divided into three parts, namely the population profile (Part A), the honeycomb layout design for crime prevention and community safety (Part B), and the last part is comments and suggestions (Part C). The essence of the study is directed to Part B, which is the relationship of honeycomb layout design with crime prevention elements that have been identified, such as natural surveillance that includes layout design items, mixed development, activity generation, trapped spaces, and dead ends, view spaces, and pedestrian access. Meanwhile, natural access control elements involve building design items, avoiding blind walls, doors and windows facing the street, wall height, and lighting. At the same time, boundary clarity is measured through the division of space (zone), appropriate road design, access roads, landscaping, maintenance, and management elements, including mechanical supervision, planned supervision, complex engineering, and soft engineering. Accordingly, all the findings of this study were analyzed by inter-correlation between the variables to see the relationship and significance that occurred in the items selected to explain the study findings.

3. Results and discussion

The study's findings focus on the four main elements of crime prevention: natural surveillance, natural access control, boundary clarity, maintenance, and management. These four elements are linked to the honeycomb layout in maintaining the safety of urban neighborhoods through the measurement of variables that have been identified.

3.1. Demographic profile of respondent

The respondent profile consists of 130 men (77.4%) and 38 women (22.6%) who include the Malay race; 150 people (89.3%), followed by Chinese, 15 people (8.9%), and 3 Indian people (1.8%). Next, the highest respondent age limit category is the economically active age limit, which is 41-50 years with a total of 141 people (83.9%), compared to the age limit of 51-60 years, which is 18 people (10.7%) on the other hand the lowest is the age limit category of 31-40 years old which is nine people (5.4%). The data shows that the Malay community dominates this neighborhood because the land status is a Malay Reserve. In addition, the number of households only consists of 3 to 5 people.

3.2. Natural surveillance

The results of the inter-correlation analysis below (Table 1) show a robust correlation between layout design and activity generation (r=.97), followed by mixed development and view space (r=0.97). Meanwhile, activity generation with trapped space and the dead end is (r=0.96), and trapped space and a dead end with view space are also the same (r=0.96). Whereas view space and footpath access show (r=0.95), then footpath access with trapped space and the dead road are the same (r=0.95). Therefore, all these correlations are positive and significant at $p<0.01$. The analysis results in Table 1 show that all the correlations related to natural surveillance aim to increase public surveillance by designing spaces, landscape preparation, and windows or doors that lead to public areas. Coupled with the 'eyes on the street' approach to criminals, it causes a sense of insecurity for intruders to commit crimes (Marzano et al. 2023). It shows that natural surveillance through the ability of the environment can create clear surveillance opportunities with a view space from various angles, whether from outside or inside the building by residents or security guards through the design location of windows and doors (Laurence, 2016). Thus, there is extreme significance between natural supervision

and layout design and building design when it comes to mixed development. The rationale is to increase the generation of activities such as shops, restaurants, offices, public spaces, culture, and recreation as a connecting medium to encourage the interaction of residents while creating a sense of security (Botchwey et al., 2022). Parks and public places are also provided in locations that are easy to see within walking distance through a clear line of sight to avoid trapped spaces (trapped spaces and dead ends/entrapment spots). Each unit is connected within walking distance of 400 meters from the center of the neighborhood with a cul-de-sac that does not exceed 75 meters to facilitate the identification and detection of foreigners (Bajunid et al., 2018a). This footpath access is continuous in residential areas, neighborhood centers, business areas, and public focus areas that can be seen directly from nearby premises and are not obstructed by any structure. At the same time, back alleys in honeycomb housing were also abolished to avoid hiding places for criminals or intruders who could threaten or attack the community (Harun and Jalil, 2014; Masram and Misnan, 2019). The implication is that when the community begins to feel safe, neighborhood relationships are automatically nurtured with respect, mutual appreciation, and a spirit of belonging and togetherness (Jacobs, 2016; Peng et al., 2020).

Table 1: Natural surveillance

	Layout design	Mixed development	Generate activity	Entrapment spot and dead-end	View space	Pedestrian access/ walkable community
Layout design	1.000	0.958**	0.971**	0.954**	0.963**	0.955**
Mixed development	0.958**	1.000	0.956**	0.961**	0.968**	0.952**
Generate activity	0.971**	0.956**	1.000	0.960**	0.959**	0.956**
Entrapment spot and dead-end	0.954**	0.961**	0.960**	1.000	0.964**	0.951**
View space	0.963**	0.968**	0.959**	0.964**	1.000	0.953**
Pedestrian access/walkable community	0.955**	0.952**	0.956**	0.951**	0.953**	1.000

*: Correlation is significant at the 0.05 level (2-tailed); **: Correlation is significant at the 0.01 level (2-tailed)

3.3. Natural access control

The inter-correlation analysis below (Table 2) shows a robust correlation (r=0.94) between building design and wall height, avoiding blind walls and lighting. These three variables have the same correlation value. A very strong correlation was also found between the door and window variables facing the street with the building design, which is (r=0.93) followed by the height of the wall, and the blind wall also has the same value (r=0.93). All the correlations are positive and significant at p<0.01. The analysis results in Table 2 show that all the correlations related to natural access control aim to prevent someone from entering an area/premises where he should not be. Access control can be implemented through doors with security cards, fences, landscaping, and other physical elements (Foo and Wong, 2014).

Therefore, a robust correlation exists between natural access control and building design that provides open space, not hidden, and a high level of visibility (Storrer, 2002). Next, ensure doors, windows, and foyers of residential houses face the street, open areas, footpaths, parking areas, and landscaping that do not obstruct the public view to avoid 'blind walls' (Lee and Chew-Ging, 2017; Mars and Kohlstedt, 2020). Meanwhile, the length of the car porch for houses with two floors and above does not exceed 10 feet from the building line to facilitate surveillance towards the gate from the main bedroom or the front of the upper floor of the house. In addition, the height of the fence or dividing wall does not exceed 5 feet. It is because the allowed closed space does not exceed 2 feet from the ground level, with the fence design being 50 percent transparent and difficult to climb to facilitate the surveillance and view of the neighbors. Furthermore, the placement of the building fence also does not block the view of the public space. The design and position of elements such as partition walls, garbage dumps, low roofs, or tree branches do not help criminal activities, including providing bright lighting at night so that a person's face can be seen at a distance of 10 meters (32 feet) and recorded clearly by CCTV (Felson and Eckert, 2018; Foo and Wong, 2014).

Table 2: Natural access control

	Building design	Avoid blind wall	Doors and windows facing the street	Wall height	Lighting
Building design	1.000	0.935**	0.930**	0.943**	0.941**
Avoid blind wall	0.935**	1.000	0.931**	0.934**	0.930**
Doors and windows facing the street	0.933**	0.931**	1.000	0.938**	0.937**
Wall height	0.933**	0.934**	0.938**	1.000	0.943**
Lighting	0.941**	0.930**	0.937**	0.933**	1.000

**: Correlation is significant at the 0.01 level (2-tailed); *: Correlation is significant at the 0.05 level (2-tailed)

3.4. Territorial reinforcement

The results of the inter-correlation analysis below (Table 3) show a strong correlation between appropriate road design and access roads (r=0.89), followed by spatial division (zones) and access roads (r=0.87), followed by landscape with the division of space (zone) (r=0.86). All the correlations are positive and significant at p<0.01. The results of the analysis in Table 3 show that all correlations related to boundary clarity show the ownership of an area. Clear marking of public and private room boundaries

can be implemented by using physical elements such as fences, gates, landscaping, and others (Barnett, 2016). Therefore, there is a strong correlation between boundary clarity and appropriate road design. Circulation in honeycomb housing is designed to isolate through traffic so that the neighborhood does not experience noise problems due to the volume of vehicles. At the same time, avoid road design or sharp bends with sudden gradients. Every Honeycomb neighborhood vehicle must slow down at the entrance intersection. The car does not have a chance to regain speed. This is because the longest straight stretch of the distribution road is less than 150 meters (500'). After slowing down to enter the cul-de-sac, the longest straight stretch of road is only 25 meters (80').

Meanwhile, the road loop in front of the house caused the vehicle to slow down even more. Therefore, in honeycomb housing, the maximum distribution road is 40 km/h, the straight stretch from the streets into the cul-de-sac maximum is 20 km/h, the loop road in the yard is 10 km/h maximum, and the walking speed is estimated at 6 km/h. Yellow lines and humps are also applied to reduce speed by setting a speed limit in residential areas of 25-30 km/hour, as suggested by the Public Works Department (PWD) for safety purposes (Aziz and Zulkifli, 2018). It shows that the cul-de-sac symbolizes the separation of settlements with the use of automobiles (Marzano et al. 2023). This is compared to terraced housing, whose circulation system creates a traffic route in front of the house, allowing for traffic hazards and the risk of accidents in the neighborhood (Bajunid et al., 2018b). Boundary clarity is also significant, with a clear division of space (zone) between private, semi-private, and public spaces (Newman, 1997). This division of space has a certain function that is capable of creating a sense of belonging (sense of belonging) and influencing the residents' attitude of concern for common safety (Zaino and Abbas, 2020). Spatial divisions such as public zones are access roads accessible to all residents. At the same time, the semi-public zone involves community centers in the neighborhood. A semi-private zone, such as an open space for a neighborhood and a private zone, refers to one's yard (Cozens, 2013).

Furthermore, in the honeycomb layout design, only one entrance is used for control and protection. Restricted paths with access restrictions facilitate the identification process for foreigners who enter this area without purpose (Marzano et al. 2023; Newman, 1997). The preference is personal so that residents are free from fear in their community (Sennett, 2018). Landscaping in a honeycomb layout also practices ecological distance measures for indoor distance (personal matters) is ½ to 1½ feet, emotional space (current affairs) is 1½ feet to 4 feet, social length (saying hello, saying hello) is 4 to 12 feet and public clearance ("familiar"/signal) is 12 feet more (Lee and Chew-Ging, 2017). This practice encourages social interaction in the community naturally and spontaneously (Bajunid et al., 2018b). For example, placing a playground in front of the yard of each housing unit allows parents to see and supervise their children directly (Ghazali et al., 2005; Jacobs, 1992) because its location is very close to the residence and thus becomes a focal point for each neighborhood unit. Meet face-to-face and chat for recreation (Boeri et al., 2022; Shukur et al., 2016). This playground is also decorated with a beautiful landscape with trees to control and lower the ambient temperature (external urban tropical micro-climate) (Hasan et al., 2019; Sepe, 2021; Wang et al., 2019).

Table 3: Territorial reinforcement

	Division of space/zone	Appropriate road design	Exit entrance	Landscape
Division of space/zone	1.000	0.861**	0.867**	0.862**
Appropriate road design	0.861**	1.000	0.885**	0.864**
Exit entrance	0.867**	0.885**	1.000	0.872**
Landscape	0.862**	0.864**	0.872**	1.000

**: Correlation is significant at the 0.01 level (2-tailed)

3.5. Maintenance and management

The results of the inter-correlation analysis below (Table 4) show a strong correlation between complex engineering and soft engineering (r=0.79), followed by mechanical supervision and planned supervision (r=0.78). All the correlations are positive and significant at $p<0.01$. The analysis results in Table 4 show that all the correlations related to maintenance and management require regular operation and continuous service by the management, residents, owners, and the community. Therefore, there is a strong correlation between maintenance and management with mechanical surveillance through electronic and mechanical tools such as lighting, CCTV, security mirrors, security alarms, intercoms, etc. Meanwhile, planned surveillance involves police patrols, security guards, neighborhood groups, RELA, and community policing (Sutton et al., 2021). Maintenance and management have a positive relationship with civil engineering, such as road furniture, outdoor signs, lampposts, etc. For example, the sign's location is on the main route, entrance and exit doors, or activity nodes to encourage multi-functional street furniture by using structures and building materials that are suitable, durable, and not easily damaged (Zubi, 2018). For example, lampposts can be used to install signs and CCTV that do not disturb residents' comfort while preventing crime (Storrer, 2002). In comparison, soft engineering involves planting shrubs with a height not exceeding 0.9m (3') on footpaths and areas requiring a high level of natural surveillance (Hasan et al., 2019). This requirement

does not conflict with Act 133 (Section 36) of the Roads, Drains and Buildings Act 1974. Next, avoid planting trees near the roofs and windows of buildings so that the trees do not cover the doors and windows and interfere with the lighting of lights, signs, CCTV, and other security equipment (Hamzah et al., 2021). Soft engineering also acts as a heat-absorbing agent, bird habitat, and health therapy (Sennett, 2018; Sim, 2019). Therefore, Honeycomb Housing strives to balance the urban ecosystem by practicing green housing and green neighborhoods as required by the Housing Planning Guidelines (Bajunid et al., 2018a).

Table 4: Maintenance and management

	Mechanical surveillance	Organized surveillance	Hard engineering	Soft engineering
Mechanical surveillance	1.000	.781**	.770**	.758**
Organized surveillance	.781**	1	.762**	.754**
Hard engineering	.770**	.762**	1	.789**
Soft engineering	.758**	.754**	.789**	1

**. Correlation is significant at the 0.01 level (2-tailed)

4. Discussion

This study indicates that honeycomb layout design can sustain crime prevention and urban neighborhood safety through natural surveillance, access control, boundary clarity, maintenance, and management. All sub-elements measured confirm the existence of a positive relationship with a very strong degree of correlation between natural surveillance and natural access control, as well as a strong correlation between boundary clarity and maintenance and management. It is because honeycomb housing practices "Crime Prevention Through Environmental Design" (CPTED), which is based on "eyes on the street," "defensible space," and "broken windows" in its layout (Bajunid and Abbas, 2012; Marzano et al. 2023; Shamsuddin and Hussin, 2013). Therefore, it benefits the community that lives in the neighborhood. In particular, the guarantee of safety, peace, and order from the interference of strangers or intruders, and children can play outside the house without parental supervision (Boeri et al., 2022; Foo and Wong, 2014; Newman, 1997).

The hexagonal layout in this honeycomb grouping can apply a sense of community concern for privacy, and neighborhood socialization can be done for social groups with different density sizes (Harun and Jalil, 2014). Then, the problem of land waste in suburbia can be overcome compared to the lack of land in the city (Jacobs, 1992). Therefore, group housing is considered more appropriate and flexible, prioritizing personal rights and providing conducive public space, even high density for population and land use (Chęć-Małyszek, 2021). It also offers public, semi-public, semi-private, and private zones (Wang et al., 2019). Indirectly, it satisfies social life without a sense of difference and more harmony (Marzano et al. 2023). History also proves that group housing guarantees safety in addition to being the most basic and permanent human settlement (Laurence, 2016).

Moreover, the honeycomb community is formed through cul-de-sac-like streets connecting pedestrian courtyards with parking spaces, schools, shops, and commercial centers adjacent to open spaces. Its location is off the main road to prioritize the pedestrian scheme (Marzano et al. 2023). Furthermore, traffic safety can be achieved by designing cul-de-sac roads with dead ends or roundabouts that function as local roads for each residential unit. The streets surrounding the neighborhood units area are related to a network of roads that lead to other neighborhood units (Newman, 1997). Natural surveillance acts as a tool to control any element of crime because each housing unit faces the playground within walking distance and is easily visible from various angles of the residential unit (inter visibility), aiming to increase defensiveness from crime incidents. At the same time, it increases visibility so that natural surveillance can be done directly by the public. Thus, it enables a more straightforward identification process if foreigners are in the surrounding area (Barnett, 2016; Boeri et al., 2022; Chęć-Małyszek, 2021).

Physical, psychological, and psychosocial security elements are applied in a honeycomb layout to achieve an index of urban neighborhood well-being. It is in line with spatial development management planning and land use towards the people's well-being and the country's prosperity. The empowerment of acts related to urban and rural planning is also involved so that all parties comply with standards to overcome the issue of urban overcrowding, the threat of index crime and social disintegration, and strengthening development research towards world-class best planning practices (Botchwey et al., 2022; Zin, 2014; Zubi, 2018).

5. Conclusions

In conclusion, this study has demonstrated the connection between honeycomb housing layout design and crime prevention in urban neighborhoods through natural surveillance, access control, boundary clarity, maintenance, and management. The study found that inter-correlation analysis shows a positive relationship between honeycomb layout design and crime prevention, supporting the "eyes on the street" approach to ensuring safety, peace, and order from outsiders or intruders. While the honeycomb layout has potential benefits for crime prevention and urban planning, its success depends on factors such as local context, community involvement, and collaboration between

urban planners, architects, law enforcement, and residents.

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Compliance with ethical standards

Ethical considerations

This study was conducted in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. The confidentiality and anonymity of all respondents were maintained throughout the research process. Ethical approval for this study was granted by the Universiti Malaysia Terengganu Ethics Committee.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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