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The Role of Spatial Relations in Influencing Crime in Public Open Spaces of Settlements around Juja Town

Beatrice Kirongon, Moirongo Otoki, Teckla Muhoro

Centre for Urban Studies, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
Email: beatrice.kirongon@jkuat.ac.ke

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Abstract

The study focuses on the urban spatial relations influence crime along the public open spaces in Juja town, Kenya. Axial analysis component of space syntax method has been adapted to establish integration and connectivity measures of public open spaces in Juja town. While observation method established the land-use, surveillance levels, build-up densities and physical traces of urban crime. Results show that Juja town has poor connectivity with the highest connectivity rate being 40 m/street connection and the lowest being 125 m/connection. Correspondingly, global integration levels sampled street segments in Juja town is moderate 1.306521 to low of 0.915067. Notably, the street segments with low connectivity and characterised by high number of cul-de-sacs, high obstacles and closed gates frequencies resulted in high positive correlations with both reported crime and observed traces of crime. However, land-use typologies (residential, commercial, and idle) correlated positively with crime occurrence in Juja town where suitable targets are present with either poor guardianship or possible escape routes for the offenders. The research findings indicate that poor connectivity and choice measures predispose Juja town to increased crime together with poor street luminance levels that prevent inter-visibility of public open spaces especially in the evening and morning hours of the day. On the other hand, entrances/gates denoting the presence of door-to-door surveillance across the street reduce crime prevalence. The study also found that presence of idle land use patterns along public open spaces discourages people from using the street segments hence robing the street segments from street guardianship resulting in increased crime incidences.

Keywords

Crime, Spatial Relations, Public Open Spaces, Surveillance, Inter-Visibility, Space Syntax, Juja Town, Kenya

1. Introduction

Crime along public open spaces in urban areas is on a sharp rise with increasing urban populations in the dawn of rampant resource scarcity that has resulted in insignificant urban design interventions. Reported crime in Juja town, a settlement around a public university in Kenya is rapidly increasing. Crimes along public open spaces mainly streets in Juja town include, stealing, robbery with violence, muggings among others targeting properties such as phones, money, laptops and other valuables. The increase in violent crimes is a major concern to safe urban living. Researches on crime in public open spaces focus on hot and spot distributions, vulnerabilities to crime and correlation of environmental conditions under specific spatial-temporal conditions with crime vulnerabilities. The purpose of this study is to examine the spatial relations in Juja university town, in an attempt to determine how these spatial relations influence urban safety. The spatial relations of public open spaces are environmental factors that include connectivity, integration, temporal durations, land-use patterns, surveillance/inter-visibility, activity levels, types of streets, traffic flows, sidewalk availability, and conditions, luminance levels at night, among others.

Besides, this research uses the space syntax method (Hillier & Hanson, 1988) to determine the connectivity and integration levels and incorporates with other environmental attributes observed and effectively correlate with the crime incidences in Juja town. Multiple regression analysis carried out also illuminates the compounding effect spatial relations have on crime occurrences in Juja.

The research findings will clarify the parameters of spatial relations concerning spatial-temporal attributes contributing to increased crime witnessed in Juja town, subsequently informing intervention strategies for future similar developments. Additionally, findings from this research could further illuminate the space guardianship as a deterrence and/or attractant to crimes.

The research is structured into five chapters. The first chapter is an introductory to the research purpose, focus, and objective with explanations on the outline of the research. The second chapter analyzes literature on existing models and theoretical frameworks within the area of urban safety and design. Chapter three outlines the research methodology by addressing the research design, data collection and sampling techniques. Chapter four presents the data analysis and findings and finally Chapter five provides an in-depth analysis and discussions of research findings in comparison with findings from literature review.

2. Spatial Relations and Crime

2.1. Theoretical Overview; Spatial Relations and Crime in Urban Areas

Spatial relations as a system of open and enclosed urban spaces accord urban users different degree of natural surveillance necessary in wading of possible offenders because of how well these urban spatial systems enhance human contacts

and activities. The concept of natural surveillance postulated by Jane Jacobs over the years has formed the basis of criticism of urban safety theories and concepts. According to routine activity theory (Clarke & Felson, 2004), crime occurs with the convergence in place and time of a motivated offender and a suitable target in the absence of a capable guardian. Guardianship of space referred to natural surveillance or "eyes on the street" which imply the ability of the urban spatial system to sustain human contact and interactions along either the public open spaces or watching the public open spaces.

The concept of guardianship and natural surveillance of public open spaces is riddled with divergent methods of attainment of urban safety. Such that, on one hand, (Hillier & Hanson, 1988; Jacobs, 1961) advocate for increases human contact on the streets while (Newman, 1972; Newman, 2013) advocate for heightened territoriality to deter crime. The former school of thought is essentially advocating for an open spatial system while the latter is advocating for an enclosed spatial system. This research then, is an attempt to establish how human contact as necessitated by spatial relations influence crime incidences anchoring on the Routine Activity Theory that elucidates the importance of natural surveillance in form of guardianship in public open spaces where the routine nature of the urbanites activities facilitates the convergence of suitable targets and possible offenders.

The conditions necessary for crime to occur as hypothesised by Felson and Cohen compare with the existing conditions in settlements near/around university. One; majority of the university settlement's population have distinct routine activities that revolve around going to work or school early morning and returning from the same in the evening similar to Cohen & Felson's time where empowered women left home early morning for work leaving their homes as possible targets. Two, university settlement's population comprises of students, workers who are financially empowered owning electronic gadgets of high value similar to Felson and Cohen's technological advancements era hence positioning them as suitable targets.

Therefore, the presence of high number of valuable objects, increased number of unguarded homes/hostels coupled with the predictable daily activities in areas of decreased guardianship increases susceptibility of the people to crime. Unlike rural areas or suburban areas where homes are in the care of the old or home managers providing 24-hour surveillance, university settlement's population is vulnerable to property crimes targeting homes during the day. The routine and predictable nature of activities in university towns encourage criminal activities by: One, reducing the population of the town during semester breaks that would add to the optimal human surveillance; Two, leaves homes and residences without surveillance during the day when students and the general workforce is out and finally, three; the routine activities increases convergence along public open spaces between the capable offenders and suitable targets.

Routine activity theory provides the basis for crime prevention through envi-

ronmental design strategies that regard the urban spatial organization as both channels and containers of human interactions towards provision of natural surveillance. Studies looking at the issue of spatial parameters that influence crime are of significance to this research including those studies that relate urban space with crime occurrences with a focus on human interactions. Studies on the broader context of urban safety also shade light into this research by looking at crime spatial patterns.

Natural surveillance through human social interactions occur owing to the presence of activities along streets that permits encounters and further interactions to take place (Weisburd & Amram, 2014), when these activities are predictable in terms of time and place of occurrence they become routine activities that often motivate offenders. Routine activities occur in specific ecological context as explained by (Clarke & Felson, 2004; Song et al., 2017; Weisburd & Amram, 2014).

The study on crime concentration in places (Weisburd & Amram, 2014) found that crime concentrates within a small bandwidth despite the volatile nature of crime and long timelines. Weisburd & Amram (2014) study provide a lifeline for crime studies that focus on spatial nature of crime locations. Further expounding crime occurrence in place rather than neighbourhood is (Eck & Weisburd, 1995) crime places in crime theory, which defines the "place" as a small area, mainly a street corner, building or street segment. Other studies including (Hurst, 2020; Shu & Huang, 2018; Tseng et al., 2004; Weisburd & Amram, 2014) have studied crime at micro level by seeking to understand the character of crime hotspots. The advantage of "Micro" crime and place studies is the site-specific nature of places unlike macro studies where obscuring influence of wider or larger geographic forces are eminent.

Specific studies on spatial crime patterns delve further into the character of crime hotspot spaces. For instance Brantingham & Brantingham (1993) as cited by (Hurst, 2020) classified urban locations into three; Crime Attractors, (places known for criminal opportunities drawing motivated offenders to it); Crime Generators, (places where people assemble for non-criminal activities but tempts motivated offenders to commit crime); finally Crime-Neutral Sites, (places not known for criminal activity and carries limited temptation prospects). Similarly, owing to the fact that crime clusters at a given crime hot-spots, characterisation of crime locations in cities is possible. Weisburd et al. (2009) as cited by (Weisburd & Amram, 2014) found that downtown areas of Seattle registered more localised crimes while the street network provided a widely dispersed crime hotspots across the city implying that crime in urban areas are not clustered in specific "bad" locations rather spread out around the city. Even within the same street, crimes cluster in segment(s) as suggested by (Eck & Weisburd, 1995; Hurst, 2020; Weisburd & Amram, 2014). Cumulatively, the general character of crime hotspots is definitive in informing crime prevention strategies such as Territoriality or defensible spaces.

Brantingham & Brantingham (1993) further described three of Kelvin Lynch elements of urban form; *edges, pathways and nodes* as constituting an individual's framework of activity Space (Hurst, 2020), beyond which exists the awareness Space. Nodes are described as particular locations characterised by high levels of non-criminal activities while the travel lines between nodes are the pathways and finally the edges are boundaries that physical or perceptually distinguishes one area from another (Hurst, 2020; Song et al., 2017). It is at the interface of the edges and awareness spaces that criminal activity increases by over 300% as noted by Brantingham & Brantingham (1993) as cited by (Hurst, 2020) due to the characteristic attribute of increased transiency and brief residency of edges (Hurst, 2020; Song et al., 2017) and reduced territoriality (Newman, 2013).

On the other divide, several studies on planned university towns also illuminated spatial relations influence in crime and useful lessons can be drawn for unplanned towns around universities, referred here as settlements around universities. One such study on university towns safety relating campuses and their neighbourhoods have found that parameters such as accessibility, transportation, roadways and pathways positively influence crime rates in university town (Morta et al., 2009; Tseng et al., 2004). This is supported by (Fisher & Nasar, 1992; Fisher, 1995) in that proximity to high-crime areas significantly increases theft rate and that places beyond an individual's awareness space register less crime rates (Robinson & Roh, 2001) contrary to (Hurst, 2020) findings that crime increases beyond the edges. Nonetheless, earlier studies by Schmid (1960a, 1960b) as cited by (Song et al., 2017) place the central business district and its immediate surrounding as crime hot spots in urban areas which also contradicts (Weisburd & Amram, 2014) findings that place downtown areas as crime hotspot areas. Traditional linear streets with strong inter-visibility according to (Cozens et al., 2001) protects from crime regardless of the dominant socio-economical variations of the neighbourhood.

While Schmid's (1960a, 1960b) study offers broad pointer to where crime occurs in university towns, (Fox & Daryl, 1985; Shu & Huang, 2018) identify specific place characteristics such as density measures, visibility and accessibility measures as influencing crime in that increased density increases anonymity while reducing territoriality reduces. Similarly, Shu & Huang, (2018) looks spatial aspects such as land use patterns, street types, inter-visibility of front doors (constitutedness), proximity of permitted industries, pedestrian walkways, and street lighting, connectivity, and space use patterns in exploring vulnerability to snatch theft crimes.

According to (Monk, 2010) as cited by (Shu & Huang, 2018), study that focused on target vulnerability to crime, crime was found to occur based on the age of the target, where the elderly are robbed during the day while the youth early morning and late evening based on routine activities of the target in question. Regarding temporal aspect of crime occurrence, findings by Monk as cited by (Shu & Huang, 2018) found that places with the two extremes of pedestrian

flow are at a higher risk of experiencing crime unlike areas of medium flow pedestrian traffic attributing it to the degree of guardianship/surveillance provided by pedestrian flow on streets. This connotes that both congested and segregated urban spaces are prone to crimes and insecurity.

2.2. Conclusion

In conclusion, crime attractants in urban areas according to research are those areas that afford possible offenders the good chances of committing a crime and getting away with it. The urban environmental characteristic therefore plays the role of either aiding or abating criminal elements. Some of these definitive characteristics as illustrated above revolve around human interactions in urban spaces as necessitated by visibility and accessibility levels, territoriality, presence of people, or the spatial character of urban space including urban density, land use patterns, constitutedness, luminance and connectivity. The understanding of human interactions in space and the spatial relations of space are therefore vital in understanding crime in settlements around universities.

3. Empirical Investigation

Discussions on the research methods adopted for the research is expounded, ranging from the sampling of streets, spatial relations from map analysis variables and environmental variables, traffic flows and human activities in different temporal durations, and the crime variables. Crime recorded from both police records and the observation of physical traces against the spatial variables is illustrated.

3.1. Pilot Survey

The study commenced with a systematic field reconnaissance survey of the study area using **Figure 1** as the base map. The survey conducted aimed at establish the general trend of spatial pattern of the public open spaces as illustrated in **Figure 2**. The survey also intended to ascertain the problems and challenges magnitude and frequencies existing in different spatial systems within the study area. Finally, the pilot study by exposing the pertinent problems aided in fine-tuning the environmental variables together with crime variables while informing the suitable data collection tools and methods.

3.2. Crime Variables

3.2.1. Juja Police Crime Records

The predominant types of crimes in Settlements around universities in Kenya according to (Aineah, 2018) include theft, muggings, rape and in some few instances death as reported by (Murenga, 2019). Notable, majority of the reported crimes occur either during morning hours or during evening hours (Ndung'u, 2015). While researching on the spatial parameters of crime occurrence,

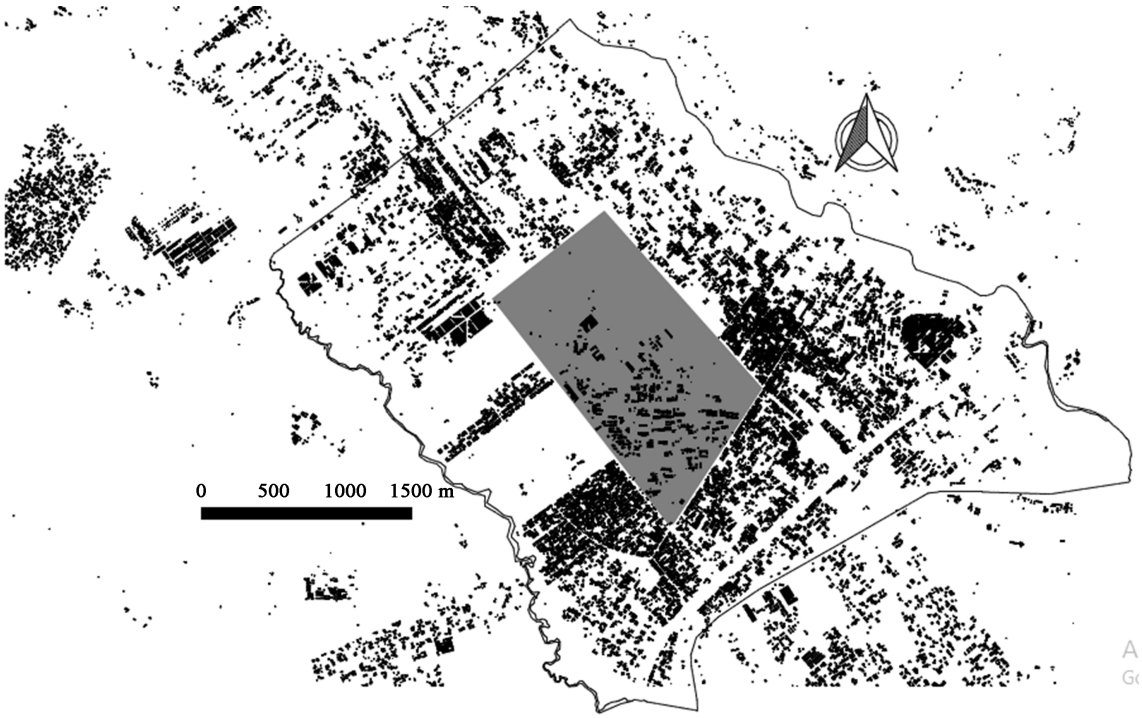

Figure 1. Juja Figure Ground Map.

Figure 2. Juja Axial Map (Author, 2022).

(Stavrou, 2002) found that 50% of thefts and muggings occur in public spaces while burglary and robberies occur in shops and other enclosed establishments. Similar findings by Stavrou (2002) place personal crimes in Kenya as the most frequent (snatching/theft 22%, robbery 37% and physical assault 18%) where in terms of time of occurrence, muggings and snatching occurred during the day while physical assault at night at 76% and 51.7% respectively. Therefore, due to the even distribution of crime locations by Stavrou (2002), this research considers the crimes occurring in both enclosures and open spaces in establishing rea-

sonable relations with public open spaces' spatial relations.

3.2.2. Observation of Physical Traces of Crime

The research adopts the use of both police crime records from Juja Police station for the last five years and observed physical traces of crime. Crime records from the police on; muggings, stealing, robberies, rape, and murder, retrieved lacked specific locations of crime occurrence necessitating the use of observation technique to record place specific crime instances. The use of observation of crime traces takes into account the unreported crimes, while highlighting the prevalence of crime by recording the various fortifications and self-preservation used by urban dwellers.

3.3. Spatial Relations Variables

The description of spatial-temporal factors considered in this study will be demonstrate below:

3.3.1. Map Analysis Variables

The map analysis involved the use of Depthmap UCL software to analyse axial maps for three variables namely; integration, connectivity and choice. The map output is colour coded, with red axial lines depicting high values while blue axial lines indicating low values.

Integration

The measure of how well public open spaces are integrated forecasts the To-Movement. To-movement is the movement to a space as a destination from all other spaces (Moirongo, 2011; van Nes & Yamu, 2021). Integration of public open spaces was explored from both global and a local perspective as Global integration (Rn) and Local integration (R3) respectively. Integration measures the degree ofaccessibility, whereby, global integration deals with longer journeys while local integration correlates better with short journeys (Cozens et al., 2001; Hillier & Hanson, 1988). Global integration in Juja sampled streets range from 0.915067 to 1.306521 while Local integration at radius of three turns R3 for the sampled streets range from 1.875084 to 2.948347 as in **Figure 3**. Street segments in Juja are segregated at the periphery/town boundary where axial lines are mainly blue-green. However, the integration measures increases towards the town's CBD and the Gachororo area with the highly integrated streets being the major roads within the town as in **Figure 3**.

Connectivity

Connectivity of a spatial system is the number of spaces that immediately connects a space of origin (UCL Space Syntax, 2021). The number of connectors to each street segment determined the escape routes for both the crime offenders and crime victims during a confrontation (Shu & Huang, 2018). The number of connectivity for this study ranges from 2 to 8. Streets segments in Juja have very low connectivity measures as seen by the green-blue axial lines in **Figure 4** with the exception of street segments along the main roads/streets tending towards

Figure 3. Global Integration (HH) Depth map X analysis of the Study Area (Author, 2022).

Segments	Connectivity
1	2
2	8
3	3
4	6

Figure 4. Axial Connectivity Depth map X analysis of the Study Area with the connectivity for sampled street segments (Author, 2022).

colour red from orange.

Choice

Unlike Integration, measures of choice predict the Through-Movement capabilities of public open spaces. This entails the movement passing through on the

shortest routes from all points to all points in a spatial layout, or within a predetermined radius from each axial line (van Nes & Yamu, 2021) **Figure 5**.

3.3.2. Field Observation Attributes

Street Segments Length and Width

Field observations conducted on the sampled axial lines concluded that the axial lines/street segments fall into fall under three street length categories. The longest streets, equal or more than 700 m; the medium street, between 400 m to 700 m and the shortest streets of less than 400 m. The inclusion of street length factor enables detailed analysis of crime and surveillance prospects for the streets per unit length of the street hence making comparisons viable.

In Juja town street width categories based on Street design and Manual for Urban areas in Kenya (Ministry of Transport, Infrastructure, Housing, 2022) is either residential area streets or informal settlements streets. As streets in informal settlements, they have limited right of way riddled with water and sewer infrastructure menace and inability to separate motorised transport from pedestrian transport. The streets also harbour high volumes of traffic from both pedestrians and motorised vehicles. The sampled street segments widths range from 9 m to 15 m. Throughways and cul-de-sacs street types are common in Juja settlement. Cul-de-sacs are prevalent in Gachororo area while throughway streets are common in CBD areas of Juja.

Surveillance and Inter-visibility

Other than ground surveillance from people on the street, the aspect of vertical surveillance provides a clearer picture into the cumulative surveillance of street segments fronted by low-, high-rise developments. The analysis of elements that afford direct view to the street and the obstacles that block direct sightlines determines the surveillance levels in Juja settlement. The total area of openings (windows, doors, and balconies) excluding windows above normal eye-level and the area of obstacles blocking direct views are included.

Figure 5. Choice (Norm) Depth map X analysis of the Study Area (Author, 2022).

Inter-visibility as depicted by constitutedness, which refers to the front door-to-front door inter-visibility. According to the field observation, inter-visibility in Juja sampled streets is dependent on the obstacles that block sightlines whereby the street segment is:

- Constituted when less than a third obstacles block direct visibility per unit length of street;
- Moderate constituted between a third and two third obstacles per unit length of street segment block direct visibility;
- Un-constituted when more than two third obstacles per unit length of street segment block visibility is blocked by obstacles.

Temporal Durations

The temporal durations impact on crime in urban areas have been alluded to severally as seen in (Brower & Carroll, 2007; Mburu, 2013; Shu & Huang, 2018) articles. The predictable routine activities occur in line with the prevalent socio-economic activities hence predisposing urbanites to criminal attacks. In Juja settlement three temporal durations according to the field observations is evident including:

- Morning: 6.00 AM - 10.00 AM; characterised by traffic flow to work or study and high activity density;
- Noon: 10.00 AM - 2.00 PM; characterised by high traffic flows and high activity density especially in commercial streets;
- Evening 2.00 PM - 6.00 PM; characterised by high traffic volumes from work and or study and high activity density.

Traffic flows

Based on the field observations, the traffic flow adopted was based on data collected from three temporal periods. Traffic flow has been categorised into pedestrian traffic flow; signifying the people on foot; Motorised traffic flow denoting all powered means of movement (motorbikes, tuktuks, cars), and Non-motorised traffic flows which connotes the non-powered modes of movement (bicycles, trolleys, hand pulled carts). The analysis of traffic flows enables the categorization of high or low traffic for the sampled spaces while projecting the risk of crime against the combined effects of temporal and spatial attributes analysis.

Land use typologies

Based on the field observations, the land use typologies adopted for the study were not defined by the official land use zoning by the town planning departments but rather by the predominant/actual land use observed. The streets were therefore categorized as being commercial, residential, or idle land uses. A street is considered:

- Commercial if more than half of the establishments are commercial;
- Residential if more than half of the establishments are residential;
- Idle if more than half of the establishments/usage is undeveloped, farming, and or undefined.

This categorization made possible by determining the ratio of the total areas of space under each category under the total area of space along a street segment.

Building Density

The density of build-up plots along the sampled street segments enabled the understanding development levels along the street segments. The number of buildings fronting both sides of the street was tallied in relation to the total number of undeveloped plots.

Pedestrian Walkability

Based on the field observations pedestrian walkability, which involved the presence and the quality of sidewalks, fell into two categories; poor walkability and good walkability. Studies on snatch theft vulnerability by (Shu & Huang, 2018) found that areas that lack sidewalks are vulnerable to snatch theft crimes due to the congestion of different movement modes. Walkability along the sampled street segments in Juja is poor owing to the lack of sidewalks.

Luminance

Luminance levels based on the field observation in Juja constituted both public streetlights and private building lights. According to (Makworo, 2012; Makaa, 2019) the width of an area illuminated by a lighting fixture is equal to the height of the lighting fixture from the ground. Such that street lighting provides a wider luminance where else, building lights provides a lower luminance width. The sampled street segments are poorly lit with the number of lighting fixtures per unit length of street being as low as 0.8% and the highest being 2.9%. Lighting and surveillance go hand in hand, following therefore that poorly lit public open spaces are prone to more crimes due to poor surveillance even with the presence of people along the streets.

4. Data Analysis

4.1. Street Activity Correlated with Surveillance Parameters

There exists significant positive correlation between mobile street activities with area of balconies overlooking the streets at 0.930. However, the presence of high walls along the street presented a strong negative correlation (−0.980) with mobile activities as in Table 1.

Similarly, area of doors, and balconies facing open spaces correlated positively with static activities at 0.940 and 0.988 respectively. While negative correlations existed between static activities and high walls at −0.975 as shown in Table 1.

4.2. Land-Use Patterns and Street Types Correlated with Pedestrian Traffic

Early morning pedestrian movement returned a strong negative correlation with idle land use (−0.990) while noontime pedestrian flows correlated negatively with idle land uses (−0.934) and positively with commercial land uses (0.903). Finally, evening pedestrian flows correlated negatively with idle land uses (−0.974) as in Table 2.

The cul de sac streets correlated negatively with gates along the streets (−0.986) and residential land use (−0.100). While gates along the street segment

Table 1.Street Activity Correlations with Street Surveillance Parameters (Author, 2022).

Correlations										
		StaticActivitie	MobileActivitie	AreaWindow	AreaDoor	AreaBalconie	OpenEntranc	HighWall	Medium Wall	NoWall
Static Activities	Pearson	1	0.971*	0.316	0.940	0.988*	0.633	−0.975*	−0.400	0.908
	Sig. (2-tailed)		0.029	0.684	0.060	0.012	0.367	0.025	0.600	0.092
Mobile Activities	Correlation	0.971*	1	0.375	0.843	0.930	0.565	−0.980*	−0.216	0.798
	Sig. (2-tailed)	0.029		0.625	0.157	0.070	0.435	0.020	0.784	0.202
Area Windows	Correlation	0.316	0.375	1	0.051	0.187	0.819	−0.191	0.594	−0.027
	Sig. (2-tailed)	0.684	0.625		0.949	0.813	0.181	0.809	0.406	0.973
Area Doors	Correlation	0.940	0.843	0.051	1	0.981*	0.517	−0.907	−0.686	0.996**
	Sig. (2-tailed)	0.060	0.157	0.949		0.019	0.483	0.093	0.314	0.004
Area Balconies	Correlation	0.988*	0.930	0.187	0.981*	1	0.574	−0.963*	−0.538	0.962*
	Sig. (2-tailed)	0.012	0.070	0.813	0.019		0.426	0.037	0.462	0.038
Open Entrance	Correlation	0.633	0.565	0.819	0.517	0.574	1	−0.458	0.028	0.467
	Sig. (2-tailed)	0.367	0.435	0.181	0.483	0.426		0.542	0.972	0.533
High Walls	Pearson	−0.975*	−0.980*	−0.191	−0.907	−0.963*	−0.458	1	0.387	−0.877
	Sig. (2-tailed)	0.025	0.020	0.809	0.093	0.037	0.542		0.613	0.123
Medium Walls	Pearson	−0.400	−0.216	0.594	−0.686	−0.538	0.028	0.387	1	−0.747
	Sig. (2-tailed)	0.600	0.784	0.406	0.314	0.462	0.972	0.613		0.253
No Walls	Pearson	0.908	0.798	−0.027	0.996**	0.962*	0.467	−0.877	−0.747	1
	Sig. (2-tailed)	0.092	0.202	0.973	0.004	0.038	0.533	0.123	0.253	

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

Table 2. Correlations of Spatial Patterns and pedestrian traffic (Author, 2022).

Correlations[c]										
		Throughway	Cul de sacs	Gates	PM morning/m	P Noon/m	P Evening/m	Residential (m^2)	Commercial (m^2)	Idlelanduse (m^2)
Throughway Streets	Pearson	1	−0.088	0.121	0.066	0.192	0.041	0.118	0.529	0.013
	Sig		0.456	0.440	0.467	0.404	0.480	0.441	0.235	0.493
Cul de sacs Streets	Pearson	−0.088	1	−0.986**	−0.253	−0.433	−0.354	−10.000**	−0.601	0.135
	Sig	0.456		0.007	0.373	0.283	0.323	0.000	0.199	0.433
Gatesalong Street	Pearson	0.121	−0.986**	1	0.409	0.577	0.501	0.986**	0.714	−0.293
	Sig.	0.440	0.007		0.296	0.211	0.249	0.007	0.143	0.353
Pedestrian morning/m	Pearson	0.066	−0.253	0.409	1	0.975*	0.994**	0.250	0.792	−0.990**
	Sig	0.467	0.373	0.296		0.013	0.003	0.375	0.104	0.005

Continued

Pedestrian Noon/m	Pearson	0.192	−0.433	0.577	0.975*	1	0.985**	0.433	0.903*	−0.934*
	Sig	0.404	0.283	0.211	0.013		0.007	0.283	0.049	0.033
Pedestrian Evening/m	Pearson	0.041	−0.354	0.501	0.994**	0.985**	1	0.349	0.816	−0.974*
	Sig	0.480	0.323	0.249	0.003	0.007		0.325	0.092	0.013
Residential (m^2)	Pearson	0.118	−10.00**	0.986**	0.250	0.433	0.349	1	0.613	−0.129
	Sig	0.441	0.000	0.007	0.375	0.283	0.325		0.194	0.435
Commercial land use (m^2)	Pearson	0.529	−0.601	0.714	0.792	0.903*	0.816	0.613	1	−0.703
	Sig.	0.235	0.199	0.143	0.104	0.049	0.092	0.194		0.149
Idle land use (m^2)	Pearson	0.013	0.135	−0.293	−0.990**	−0.934*	−0.974*	−0.129	−0.703	1
	Sig.	0.493	0.433	0.353	0.005	0.033	0.013	0.435	0.149	

**Correlation is significant at the 0.01 level (1-tailed).*Correlation is significant at the 0.05 level (1-tailed).

signified residential land use as shown by the strong positive correlation (0.986) as seen in Table 2. The presence of gates opening to the public open spaces implied that the predominant land use pattern is residential which the reduced number of cul de sacs also signify.

4.3. Spatial Attributes as Predictors of Crime in Juja Town

Multiple regression of the combined effect of all the observed physical traces of crime in Juja analysed against both the map analysis attributes and spatial attributes obtained from observation. This analysis shows the spatial predictor variables for crime in Juja for both the map analysis variables and the field observation variables. The combined effect on crime in Juja per street segment; taken as the summation observed crime variables' rate per unit length of street segment, also exposes crime vulnerability along the public open spaces of Juja. Findings indicate that vulnerability to crime; recorded as sum of all observed crimes per unit length of street is high at street segment S01 at 1.34, followed by segment S03 at 1.208333 while Street segment S02 and S04 recorded the lowest crime vulnerability at 0.29 as shown in Table 3.

However, the crime predictors for temporal-spatial field observed variables include Obstacles length, throughway streets, and idle land use together with pedestrian traffic at noon, NMT traffic at noon and evening. However, only the obstacles length, NMT evening and throughway streets as crime predictors have coefficient values above 0.4 as seen in Table 4. Therefore, the length of obstacles, throughway streets and the NMT traffic flows influences the crime in Juja public open spaces. Whereby, increased obstacles results in increased crime recorded at 1.646 while an increase in the number of throughway streets results in reduced crime evidenced by the strong negative correlation of −6.657 as in Table 4 below.

4.4. Inter-Visibility as a Predictor of Crime in Juja

Inter-visibility as measured by the area of openings that face the street segments, gates that open up to the street segments and the street luminance levels was regressed with the combined crime effect along the street segments. The multiple regression analysis indicated a strong positive correlation with area of windows at 0.964 and a strong negative correlation with open entrances and luminance at −0.604 and −0.812 respectively as seen in Table 5.

The findings show that increased luminance of public open spaces and entrances opening to the street results in a reduction in the combined crime effect.

Table 3. Combined Effect of Crime along Juja Public Open Spaces (Author, 2022).

Segments	Segment Length (m)	Combined Crime Effect
S01	100	1.34
S02	1000	0.294
S03	120	1.208333
S04	350	0.288571

Table 4. Spatio-Temporal Crime Predictors in Juja Street Segments (Author, 2022).

Model		Unstandardized Coefficients		Standardized Coefficients	95.0% Confidence Interval for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
1	(Constant)	1.428	0.000		1.428	1.428
	Obstacles Length (m)	−1.646	0.000	−0.990	−1.646	−1.646
	Throughway Streets	−6.657	0.000	−0.057	−6.657	−6.657
	Idle land use (m^2)	−0.005	0.000	−0.051	−0.005	−0.005
2	(Constant)	−1.216	0.000		−1.216	−1.216
	Pedestrian Noon/m	0.062	0.000	1.034	0.062	0.062
	NMTNOON	−0.234	0.000	−0.169	−0.234	−0.234
	NMT Evening	2.240	0.000	1.112	2.240	2.240

Table 5. Inter-Visibility Predictors of Crime in Juja Street Segments (Author, 2022).

Model		Unstandardized Coefficients		Standardized Coefficients Beta
		B	Std. Error	
1	Constant	1.563	0.000	
	Area Windows	0.948	0.000	0.964
	Open Entrances	−17.322	0.000	−0.604
	Public Lighting	−49.029	0.000	−0.812

However, the same findings seem to indicate that crime increases with an increase in area of windows along the street segment contrary to "eyes on the street" (Jacobs, 1961) and human contact prospects by (Gehl, 1989).

4.5. Map Analysis Variables as a Predictor of Crime in Juja

Multiple regression of the combined crime effect along street segments with map variables showed that global integration (HH), Local integration (HH) R7 and choice all influenced crime occurrence. However, high global integration values resulted in increased crime at 0.903 while increased choice results in reduced crime occurrence as seen in the negative correlation of −1.457. The effect of local integration (HH) R7 on crime is however negligible at 0.131 as illustrated in Table 6.

Juja street segments are moderately integrated except for the street segments at the edge of the town that are highly segregated. Global integration in the sampled streets in Juja is relatively high, ranging from 0.915067 to 1.306521 while Local integration at radius of three turns R7 for the sampled streets range from 1.875084 to 2.948347 as in Table 7. On the other divided, the likelihood for street segments to be passed through as the shortest route in Juja is very low due to the low Choice values. Therefore, the street segments in Juja are prone to high crime levels due to high global integration and very low choice values.

5. Conclusion

Research findings indicate that Poor connectivity and choice measures in Juja

Table 6. Map Analysis Variables as Crime Predictors (Author, 2022).

Model		Unstandardized Coefficients		Standardized Coefficients	95.0% Confidence Interval for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
1	Constant	−3.200	0.000		−3.200	−3.200
	Integration (HH)	3.220	0.000	0.903	3.220	3.220
	Integration (HH) R7	0.649	0.000	0.131	0.649	0.649
	Choice (Norm) R7	0.000	0.000	−1.457	0.000	0.000

Table 7. Integration values for Cluster 1 - 4. Author, 2022.

Segment	Integration (HH)	Integration (HH) R3	Integration (HH) R5	Integration (HH) R7
S01	1.110183	2.059576	1.653469	1.488976
S02	1.306521	2.948347	2.123365	1.635786
S03	1.108216	1.875084	1.574036	1.402532
S04	0.915067	2.200816	1.693467	1.384476

town predisposes the town to increased crime together with poor street luminance levels that prevents inter-visibility of public open spaces especially in the evening and morning hours of the day. On the other hand, entrances/gates denoting the presence of door-to-door surveillance across the street reduce crime prevalence.

The presence of obstacles along public open spaces reduces inter-visibility hence compromising on the guardianship levels resulting in increased vulnerability of public open spaces to crime. The reduction of the predictability of possible targets' movement patterns by increasing the number of throughway streets however reduces crime prevalence.

The study also found that presence of idle land use patterns along public open spaces discourages people from using the street segments hence robing the street segments from street guardianship resulting in increased crime incidences. Similarly, the presence of high walls along street segments discourages activities, predisposing the public open spaces to crime. However, where openings, doors and balconies overlook public open spaces increased guardianship is made possible that encourages increased human activities. Correspondingly, the presence undeveloped and unused land parcels along public open spaces limits pedestrian traffic throughout the day (morning, noon and evening) and henceforth increases vulnerability of street users to crime due to limited guardianship. Human contact along public open spaces is imperative in improving natural surveillance of street segments.

However, this study also revealed that street surveillance from windows facing the public open spaces results in increased crime incidences. Further studies on the influence of vertical surveillance from windows openings on crime would shade more light into this phenomena.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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