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Original Article

Spatial macro and statistical analysis to assess built-in environment and burglary crimes in neighborhoods of Riyadh city

Turki Almutairi*

Department of Regional and Urban Planning, King Abdulaziz University, Jeddah, Saudi Arabia

ABSTRACT

Recent land use policies and built-in environment neighborhood design can made more impact in urban areas as the crime rates are increased and thus it is significant that the policy makers must understand the relation between environmental factors such as vehicular, pedestrian access, land use, socioeconomic, and crime density. Thus, this research explores the crime incidences in the residential neighborhoods using the principles of the Crime Prevention through Environment Design (CPTED), CPTED in neighborhoods in Riyadh. Nowadays, spatial analysis of crime data assists in identify the neighborhood characteristics in association to crime severity level. The study adopts the statistical analysis of multivariate or non-linear regression analysis and spatial macroanalysis model to estimate the relationship between key built environment attributes and burglaries. A GIS-based analysis was adopted to spatialize the assessment and explore the spatial and statistical correlation dynamics. The research finds that a correlation exists between the built environment attributes as predictors of crime occurrences.

Keywords: Burglary crime, CPTED, geographic information system, residential neighborhood, spatial analysis, statistical analysis

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INTRODUCTION

The crime intensity built environment impact is consequential and recently the crime place studies paid more attention.[1] Crimes are based on socioeconomic and demographic factors, and they depends on the built-in environment, performing as external force affecting the individual's attitude and behavior. The crimes' influential factors determining is crucial in reducing the costs and opposing society impacts. The relationship between the crime and urban built-in environment has explored in several developed countries, but only lesser attention is provided. The major challenge is the spreading of urban crimes with urbanization increase in most of the cities. Due to the sociopolitics and environmental poor conditions and lifestyle transformation, crime incidents have rising in the developing countries. Based on legal system, crime types differ from country to country.

Recent studies are approved on the urban built-in environment, determined the effects on crime rates. Further, crime prevention is lacking in planning and major principles negligence. However, recently, the prevention is based on the crime prevention through environmental design (CPTED) which is comprised with territoriality, control access, and surveillance. More crimes are present with social and physical disorder. The urban built-in environment physical aspect is the spatial arrangement like roads and buildings in man-made design and potential spatial contiguity association among the neighborhoods. Thus, urban built-in environment incomplete indicators quality compromised with loyal relationship between the crime and urban built-in environment.

In summary, the existing studies[2] providing lesser attention to spatial arrangements' physical aspects of urban built-in environment, causing incomplete indicators shows problematic in evaluating the loyal relationship with environmental, social, and economic factors. In developed countries, the previous relationship between the crime and urban built-in environment is highly observed. In general at microscale, the

Address for correspondence: Turki Almutairi, Department of Regional and Urban Planning, King Abdulaziz University, Jeddah, Saudi Arabia. E-mail: almutairiturki70@gmail.com

noted relationship is observed and it associated with residential robbery, violent crimes, and burglary.

In the Kingdom of Saudi Arabia, modern Western urban design is adapted and it may shows negative effect due to the increase in crime which are showing association between the crime driven through socioeconomics and planning, and urban design planning. This research is focusing on to address the research gaps in exploring the relationship among the urban built-in environment layout and city neighborhood's residential crimes. Spatial and statistical analysis is needed to understand the relationship between crimes and urban built-in environment. In addition, this research assessing the correlations between urban density, crime, population, and neighborhood's accessibility.

The study focuses on answering two main questions through the model:

- To what extent the neighborhood accessibility in large cities associated with crime rates in residential areas?
- What are the associations between the built-in environments attributes specified on crime density in neighborhoods of large city recorded with higher crime rates?

The major contribution of the study involves,

- To discover how the urban environment impact the occurrence of residential crimes and identify the crime incidences in Riyadh city, Saudi Arabia.
- To perform macro-spatial analysis and statistical analysis for urban planning processes and design to minimize crime by analyze the physical and socioeconomic factors that influence crime in urban environment.
- To predict the relationship among these factors using the statistical analysis performed.

Silva and Li[3] established set of Urban Built Environment Indicators (UBEIs) with respect to road networks and building footprints at Praia neighborhood level, Cape Verde. Single UBEIs were created and the highly relevant associations with major crime types have been explored using the regression and correlation evaluation. The major crime types selected were robbery, residential robbery, mugging, crimes with weapons, and burglary. The study outcomes revealed consistency in relationship among various crime types, recommended that poor urban built-in environment be related with crime types increase. Urban planners designed or assimilated the neighborhoods from earlier stage, for crime incidents decrease.

Hipp *et al*.[4] related the Google Street View images with machine learning approaches, exhibited major insights into criminologists, and describing the built-in environment characteristics can made an effect on crime level in certain geographical areas such as street segments. Certain important features have been included like buildings and green space, in understanding the crime location. Particular association has not clear since using Google Street View exhibiting certain limitations which cannot the season or time. In addition, all the images were of daytime images, but the crime rate shows higher rate in night time.

Thomas *et al*.[5] explored the multilevel evaluation which integrates the sociodemographic and physical characteristics elements. The neighborhoods within cities or microunits advanced to the correlation of various crime types. Temporal and spatial pattern evaluations have been made in alternative public health concern and other physical ailments. Boivin[6] provides routine activity theory and data collection is performed at Toronto city and the analysis performed using weighted regression model. The outcomes show that there exists positive association between population and crime in several tracts. The empirical results have also identified for alternative proposition such as limited crimes were recorded in larger populations. Similarly, the statement is true for the large areas such as school, workplace, and shopping.

At different spatial scales, Vandeviver and Bernasco[7] evaluated about the offenders who were considering the environmental features, choose the target, and analyze the residence level attributes and instantaneous neighborhood effect on the choice of residential burglary. Spatial data signature among the home security technologies' apparent access discussed in Hodgkinson and Andresen.[8] The security hypothesis support of residential burglary has been analyzed. Additional potential factors evaluated in Hu *et al*.,[9] with respect to environmental criminology and thus prior information plays important part.

- The existing researches[10] were thus only concentrated on evaluating the residential burglaries. The built-in environment effects on crime differentiate by crime type and the results have not been generalized.
- At the small area, data that are more specific are not available and it may due to the fact that more interesting crime-specific or crime-general patterns were not determined such as narcotic drug offenses, homicide, or assaults.[11]

METHODOLOGY

The following section describes the sample data taken and the suitable method description to analyze the data.

Study Area

This proposed study is conducted in Riyadh city, the capital of KSA. For economic activities, the city is the financial hub and it considered as fastest growing cities in Middle East with annual population growth rate is 8% as reported through Habitat.[12] The city comprised with 13 municipalities with 192 neighborhoods mentioned in Figure 1.

The city population is grown from 20,000 in 1930 to 6,506,700 million in 2018 and is expected to reach more than 15 million

by 2030. Riyadh city is pre-dominantly residential as 38.81%, followed by 27.63% non-residential areas of urban amenities, vacant land of 14%, and open space of 19.15%.[13]

Variables Selected

The variables selected for this model requires range of data comprised with population, urban density data, land use, burglaries, and socioeconomics.

Crime Data

By providing the wide range of criminal activity in cities, it has decided to focus on the single type of crime named burglaries. The major data source used for the research is the burglary reports from the Riyadh police department from January 2015 to December 2018 for both businesses and residential burglaries occurring in the city. Using the block to point analysis, the crimes are spatially distributed and represented based on spatial features. The random point distribution is defined as 500 m boundary radius around every neighborhood

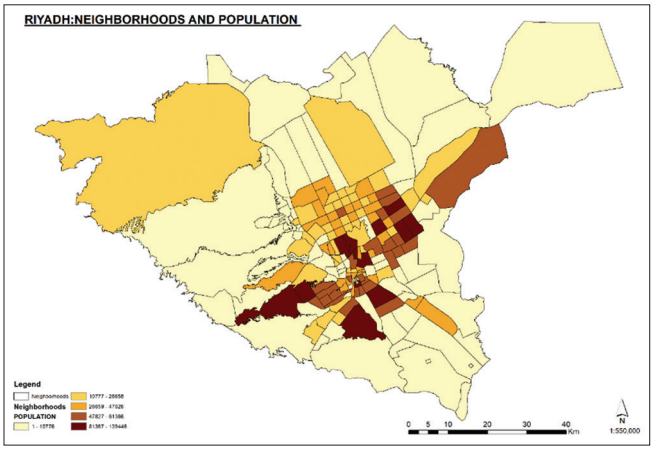

Figure 1: A map of Riyadh city with the population density data[13]

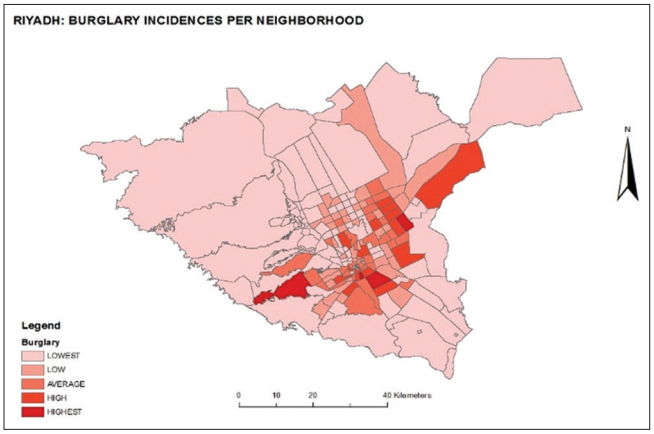

Figure 2: Spatial distribution of crime data to block points (Burglary incidence per neighborhood)

associated with reported burglaries in the area, which are inferred using GIS software to reveal the point's distribution within Riyadh, as shown in Figure 2.

An evaluation of crime data per neighborhood is shown as red areas, which are the higher crime incidences in 2018. It is observed that the highest concentration is in neighborhoods' inner city and there from distances of inner city, there is decrease in incidences.

Road density observed from GIS is used to provide insight on coverage area per neighborhood, as shown in Figure 3. The neighborhoods with high street intersection density data are directly related to the number of reported burglary cases.

Moreover, the land uses are comprised with four patterns of development such as institutional, commercial, and industrial and parks. The ratio of every land is estimated using summation of these proportions over the total neighborhood area. Using the available spatial crime data, the correlation among the land use and crimes is established.

Dwelling Intensity

The dwelling density is measure by dividing the number of dwelling units by the total land area, where this denominator has been adjusted to reflect only land allocated for residences, excluding roads, parks, and other public lands. Burglary rates are cross analyzed with population data per neighborhood to identify the higher crime rates. It has argued that this validates the findings of same studies which indicate an association among the higher population in polygons and crime incidences.

Buildings Areas (Dwelling Density)

The spatial representation of the crime rate per neighborhood based on the densification of built-up areas suggests that the inner core of the city appears to be a hotspot for crime, with decreasing levels of crime with distance from this center.

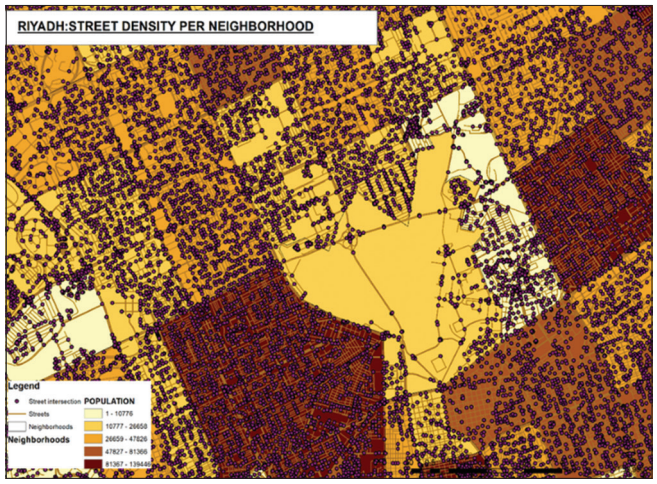

Figure 3: Intersection density

Socioeconomic Data

There are multiple sociodemographic factors affecting the crime including number of households, education, age, gender, and unemployment indicated from Yue and Zhu.[14] However, these kinds of data are not able to record and this study is then focuses on median household income scores obtained from 2018 consolidated demographics data for Riyadh city based on census data. The median household income score uses values from 1 to 5 (from the highest to the lowest levels of median household income), assigned based on the quintile classification of median household income.

Statistical Data Collection

The major data source used for the research is the burglary reports from the Riyadh police department from January 2015 to December 2018 for both businesses and residential burglaries occurring in the Riyadh city. Further, the statistical data are also collected to perform the in-depth analysis. It provided a means of interpolating robbery patterns in the research.

Research Design

A multicriteria analysis was used to understand the implications of urban structure on crime rate in Riyadh city. In this analysis, both statistical and spatial analyses were combined to model different scenarios, using the criteria against the occurrence of crime to identify hotspot areas at neighborhood levels. The purpose of the study is to investigate the relationship between built environment and crime occurrences in neighborhoods with highly crimes in Riyadh city (the city has been chosen as an example on large cities due to the lack of neighborhood concept in large city). As known, the relationship between built environment and crimes has been established by main theories such as (Eyes on street by Jacobs), defensible space theory by Newman. Further, this concept has focused by other scholars such as Jeffery till the approach of CPTED has been defined and the principles include territoriality, access control, image/maintenance, surveillance, target hardening, and activity support. Although the relationship has still been complex and there has been debate in this regard, the application of these theories has proved its success particularly in Western cities and had positive impact on crime reduction.

Conceptual Framework

This is an extensive topic, as such the model focused on the CPTED principles with key issues including street design and interactions (walking), land uses, and social economic status. The model of the study is outlined in Figure 4. Here, the independent variable is considered as burglary crime, moderating variable is socioeconomic design, and the dependent variable is street design and neighborhood interactions. The data collection is focused on GIS database.

Initially, the data collected are verified for proper data usage in modeling the variables. Interpolation approach can be consider

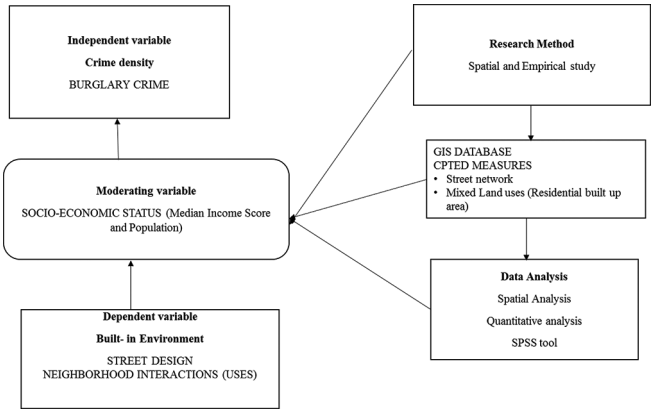

Figure 4: Conceptual framework

to identify areas within spheroid and hot spot analysis, used for point clusters with central point used for extending the crime incident probability. The relationship between data collection and crime incidence's neighborhood measure is constructed. The correlation between these two variables is used to identify the crime variation per neighborhood and evaluates the impact of other factors on crime rates.

Data Preparation

ArcGIS software from Esri is used for the analysis, multiple verification is performed on obtained data,

i. Position accuracy – All GIS datasets were assessed on whether they are located within Riyadh city. The geographic coordinate system was adopted for the study to harmonize with the open-source datasets.
ii. Attribute accuracy – The attribute data were checked and cross-referenced for validation. Gaps were checked in the columns to ensure that the attribute represented was accurate and a valid representation of the data. The accuracy checked that the attributes are well labeled and understood.
iii. Logic consistency – This involved validation that the data are relevant to the study and that it can be used in the analysis to reduce inconsistencies in the findings.
iv. Data availability – The data were checked that it was recent and up to date to be viable to assess the spatial patterns over 192 neighborhoods in Riyadh.

Proposed Model

The proposed model was created to investigate the relationships between specific built environment attributes, namely, street intersection, residential density, and land use against the occurrence of crime. Correlation and regression analysis methods are applicable in modeling using IBM SPSS tool to indicate the associations between variables where changes to one variable are accounted for in other given variables. In this case, linear regression modeling is employed to detailed spatial data to determine the correlation between the aforementioned built environment factors and

burglaries in residential neighborhoods. The Dominance-based Rough Set Approach (DRSA) was used in the linear summation of built environment indicators to reflect urban environmental quality in terms of land use clustering, street density, residential neighborhoods, and an exploration of the income per neighborhood.

RESULTS

The following section describes the proposed model results and its suitable interpretation.

Socioeconomic Analysis

A check was also carried out on the impacts of socioeconomic demographics and crime, using Pearson's correlation coefficient to measure the strength and direction of the relationship between these two variables. The analysis indicates a value of R as 0.2355, which is a negative correlation, suggesting that there is a weak relationship between household income and crime. This result is attributed to the fact that income alone has a weak association with burglaries, supporting the inference that the rate of burglaries is associated with a range of environmental factors. Hence, comprehensive analysis of income and burglary data, as indicated in the boxplot in Figure 5 represent that crime rates increase when household income category is low and crime rates decrease for individuals having more household income. This is a clear illustration of the inverse relationship between income and crimes. With several outliers noted, at the 72,001–12,000 category, we have more dispersion of the data points from mean, unlike any other type. Crimes rates are most dense in the 120,000–150,000 earning household earning neighborhoods.

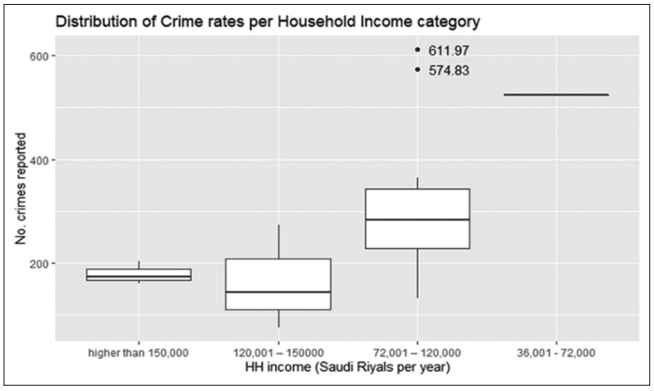

Figure 5: Distribution of crime cases across the household groups

Correlation Analysis of Built Environment

A correlation analysis was carried out to investigate the association between the combined built environment variables on burglaries. From the below table, it is observed that the significant *P*-value is minimum. Hence, this analysis indicates that maximum spatial autocorrelation between data exists suggesting that a positive association. This result is reinforced by the regression analysis where R square is 0.415928, as indicated in Table 1.

Descriptive Statistical Analysis

A summary of the descriptive statistics shown in Table 2 considered in the non-linear regression model reveals that the mean crime density in the 192 sampled neighborhoods was 228.37 crimes per square kilometer with a standard deviation of 139.75. It can be observed that the standard deviation of the independent variables does not deviate far from the mean. Table 2 indicates the summary of the model fitted.

From Table 3, dwelling density has a coefficient of 0.044 with $P = 0.025$, suggesting that it is statistically significant in predicting the number of crimes at a 95% level of confidence. For every unit increase in the dwelling density, the expected log count of the crimes per square kilometer increases by 0.044 units. Intersection density has a coefficient of 3.46, indicating that it is statistically significant in predicting crime rates ($P = 0.0494 < \alpha = 0.05$). For every unit increase in the street intersection density, the expected log count of the number of crimes increases by 3.46 units. However, mixed land use

Table 1: Summary of residual spatial autocorrelation

Global Moran's I *P* value	Adjusted R-squared	Akaike's information criterion	Jarque-Bera *P* value	Koenker (BP) Statistic *P* value	Max variance inflation Factor	Model variable significance	Model
0.000008	0.037814	2098.268698	0.074836	0.000013	1.002808	0.10	SSM
0.000005	0.040283	2096.700172	0.068968	0.000007	1.000000	0.01	SSM 2nd trial

Table 2: Descriptive statistics of model variables

Statistics	Dependent variable				
	Crime density (per km^2)	Mixed land use proportions	Residential block length	Dwelling density	Intersection density
Mean	228.37	0.073	393.27	14.17	0.086
Std. deviation	139.75	0.034	104.04	3.22	0.036

proportion is not statistically significant in predicting the number of burglaries in Riyadh city ($P = 0.28$), that said, this factor does positively impact the number of crimes from the relationship shown above by 2.29.

Interestingly, a neighborhood whose earnings range between 120,001 and 150000 Saudi Riyals per annum has a statistically significant impact on the number of crimes reports in the area, unlike the rest of the income groups. This assertion was tested in terms of statistical significance using an analysis of variance of the two models, with results shown in Table 4.

The results indicate that household income is statistically significant in predicting the number of crimes in Riyadh city at a 95% level of confidence (3 degrees of freedom, $P = 0.007 < \alpha = 0.05$). It is argued that this confirms that the incidence of crime is related to several factors and explains the negative Pearson's correlation coefficient when the relationship between household income only and crime was tested. An assessment was carried out of the significance of the fitted model in the prediction of crime rates, based on the assumptions in Table 5.

Regression Analysis

Table 5 shows the regression statistics which is one of the statistical methods used for the evaluation of relationship among the one or more independent variables and dependent variable. The multiple R-value is near to 1, it shows perfect positive relationship. R square values describe the degree in which the input variables explain the differentiation of predicted/output variable. Thus, if R-square is near to 0.7, it refers as 70% variation in output variables described from the input variables. Adjusted R square is the recent R square version which adjusting the variable predictors in regression models.

Inferential Statistics

Further, Table 6 explores the inferential statistics on the model that tests whether the data are generalizable to the broader population. From the model's summary, the Chi-square test of hypothesis applied is based on the statistic (117.091–25.031) at 24–16 degrees of freedom to give a $P = 2.220446e^{-16} < 0.05$. The null hypothesis that all the coefficients are zero is rejected and it is concluded that the model is statistically significant at $\alpha = 0.05$ significance level.

DISCUSSION

This finding is in keeping with wider studies on this topic including the assertions of Armitage and Ekblom and Newman[15,16] (1971) who argued that crime is linked to spatial layout. Several empirical studies like Yue and Zhu,[14] Armitage and Ekblom,[15] Hillier,[17] provide different definitions about the neighbourhood's operational definition, this also explored consensus on relationship of density, access, crime and urban layout.

Wang *et al*.[18] detected the relationship among the burglary distributed pattern and permeability of neighborhood with their associated study unit. The findings resulted in neighborhoods with lesser spatial or physical permeability permits only few people to enter by are related with burglary clustering. On the burglary prevention, socioeconomic barriers dealt with positive

Table 3: Estimates of coefficients and their *P*-values

Table of coefficients			
Variables	**Estimate**	**Std. error**	**Pr (>|z|)**
(Intercept)	3.3666549	0.3938265	$2e^{-16}$***
Dwelling density	0.0443600	0.0198426	0.0254*
HH. Income. 120,001–150,000	−0.3655744	0.1701605	0.0317*
HH. Income. 72,001–120,000	0.0883040	0.1692030	0.6018
HH. Income. 36,001–72,000	−0.3276977	0.3729486	0.3796
Intersection. Street. Density	3.4648016	1.7627861	0.0494*
Mixed. Land. Use. Proportion	2.2855958	2.1146332	0.2798
Numbers. of. Male. Schools	0.0022149	0.0070043	0.7518
Residential. Block. Length	0.0023853	0.0005603	$2.07e^{-5}$***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 4: ANOVA table

Model	theta	Resid. df	2*log-likelihood	test	df	Pr (Chi)
With HH. Income	1.93722	19	−282.6540			
Without HH. Income	19.77009	16	−270.4579	1 versus 2	3	0.006741

ANOVA: Analysis of variance

Table 5: Regression analysis

Multiple R	0.842922
R square	0.710518
Adjusted R square	0.614024
Standard error	86.82376
Observations	25

Table 6: Inferential statistics on the model

1. Null deviance: 117.091 on 24 degrees of freedom
2. Residual deviance: 25.031 on 16 degrees of freedom
3. A: 290.46
4. Theta: 19.77
5. Std. Err.: 6.02
6. 2×log-likelihood: −270.458

impact. Yet, the relationship between the crime distribution and permeability is not uniform over whole city geographically.

Anderson *et al*.[19] found that commercial areas typically experience higher levels of crime than closed residential areas, and zoned residential areas suffer lower crime rates than mixed use developments. This point supports the above findings indicating an association between access to residential area through the road and street network and crime.

The study finding establishes four concepts:

1. The proportion, length, and density attributes of the built environment are associated with crime density, whereby increases in these environmental values are linked to an increase in crimes. This indicates that neighborhood design alone does not drive crime, rather it is one of several key variables associated with crime vulnerability.
2. During this study, several other research areas presented themselves, either because of a gap in the literature or arising from the primary investigation. There appears to be a limited understanding of the relationship between built environment and crime on a microlevel pattern.
3. Finally, statistical analysis is performed using SPSS tool and the data are based on crime data. The correlation and regression analysis is performed. A correlation analysis was carried out to investigate the association between the combined built environment variables on burglaries. However, apart from burglary crime, more number of crimes such as theft, homicides, abuses, and other crimes are happening in urban areas. It should be considered in future and it considered as major gap.

CONCLUSION

The study explores the application of GIS statistical tools and the ability to represent the data spatially. Both correlation and regression analyses have been applied in the analysis using IBM SPSS tool. Overall, a strong correlation was noted in the crime incidence and various types of built environment data. The DRSA approach model shows a connection to all forms of crimes hotspot points determined using both spatial tools and statistical approach. However, the regression indicator is more robust in employing a correlation between the built environment and crime occurrence rate. The study had no data anomalies evidenced from the regression output which was close to one, confirming variables relationship in the GIS world. The study reflects on GIS as an essential tool in the study which complements other studies that employ data analysis enhancing research to be more valuable and accurate. Statistical and spatial modeling aimed to summarize a study's results in such a way that evaluators can observe data patterns, draw conclusions, and ultimately answer the questions that prompted the study. Models provide a snapshot of variations in the system's behavior across the study's multiple factors and levels. Having examined the relationship between built environment and crime density in neighborhoods of Riyadh city on a macroscale, the findings of the built environment measures indicated a significant relationship to crime density except the mixed land use proportion. This does not disqualify them from the model but are retained for further scrutiny.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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