Spatial Analysis of Traffic Accident Factors in Balikpapan City

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Abstract:
This study aims to analyze the relationship between land use and traffic accidents in Balikpapan City, with the goal of reducing accident occurrences. The specific objectives include identifying accident characteristics, analyzing spatial accident patterns, and examining the influence of spatial and non-spatial factors. The research employs a quantitative approach using regression analysis and spatial analysis with ArcGIS. This tool is used to map accident rates and apply Getis-Ord Gi* statistics to identify accident hotspots. The findings indicate a high severity of accidents, with 53% of victims resulting in fatalities. Motorcycles are the most frequently involved vehicle type, and accidents are predominantly caused by traffic violations and driver inattention. Residential and industrial areas are identified as high-risk locations for accidents. Hotspot analysis reveals that accident points in Balikpapan City exhibit significant clustering in several sub-districts, particularly North Balikpapan (West), Balikpapan City, Central Balikpapan, and South Balikpapan. These areas have the highest accident frequencies and are identified as accident hotspots. Further analysis using regression models shows that land use, particularly green open space (RTH), has a negative correlation with the number of accidents. A larger green space area corresponds to fewer accidents, while a decrease in green space is associated with an increase in accidents. This suggests that areas with more green space and lower urban density tend to be safer, whereas denser, high-activity areas experience more accidents.
Keywords: Traffic, Accident, Spatial, Analysis

1. INTRODUCTION

Traffic accidents are a significant issue in Indonesia, representing inefficiencies in transportation management. These accidents disrupt the movement of people and goods, leading to economic losses and a decline in both the quantity and quality of transportation services. According to Government Regulation of the Republic of Indonesia No. 30 of 2021 on Traffic and Road Transportation, transportation plays a crucial role in supporting national development and integration. It is a strategic element that contributes to public welfare and economic progress, as outlined in Law No. 22 of 2009 on Traffic and Road Transportation.

Traffic refers to the movement of vehicles and individuals within designated road spaces, whereas traffic accidents are unexpected and unintentional events involving vehicles, either with or without the presence of other road users, resulting in property damage and/or human casualties. Traffic accidents occur globally, often leading to substantial material and social losses, including fatalities. According to the World Health Organization (WHO) in 2018, someone dies from a traffic accident every 24 seconds. The rapid expansion of transportation systems has inadvertently increased traffic risks due to various factors, including rule violations, reckless behavior by drivers and pedestrians, poor road conditions, inadequate

vehicle maintenance, weather changes affecting visibility, and obstructed views caused by surrounding land use.

Transportation is a fundamental driver of urban and economic development. It facilitates the movement of people and goods, serving as a crucial link between land use and economic activities. An efficient transportation system ensures accessibility, enhances connectivity, and supports regional growth. However, as cities expand, transportation demands increase, leading to more complex challenges that require immediate solutions. The relationship between urban land use and transportation systems is reciprocal—land use patterns shape transportation needs, while transportation infrastructure influences spatial development.

Urban spatial structure, defined by the arrangement of settlements, facilities, and infrastructure, plays a key role in socio-economic activities. A well-planned spatial structure promotes accessibility and efficiency, whereas poor planning can contribute to transportation issues, including traffic congestion and accidents (Science, 2019). One of the major challenges in urban transportation is the inability of roads, vehicles, and supporting infrastructure to keep pace with economic growth and population expansion. As economic activities increase, so does the demand for transportation, leading to a surge in motorized vehicle usage. In Balikpapan City, the number of motorized vehicles has risen sharply in recent years. According to data from the East Kalimantan Provincial Police, motor vehicle registrations increased from 634,243 units in 2020 to 648,317 in 2021, and further surged to 841,472 in 2022, representing a 31.96% growth in 2022. This rapid increase in vehicle ownership exerts significant pressure on the city's transportation network, contributing to a rise in traffic accidents. According to the Balikpapan Police, several routes in the city are considered accident-prone. Between 2018 and 2023, there were 553 reported traffic accidents, resulting in 222 fatalities, 83 serious injuries, and 336 minor injuries, affecting a total of 716 victims (Balikpapan Police, 2024).

Table 1. Traffic Accident Data for Balikpapan City

Year	Number of Accidents	Fatalities	Serious Injuries	Minor Injuries	Total Victims
2018	124	3	4	126	168
2019	73	18	34	28	120
2020	47	37	5	26	68
2021	97	46	11	37	94
2022	110	67	16	77	160
2023	102	51	13	42	106
Total	553	222	83	336	716

The high incidence of traffic accidents in Balikpapan highlights a critical urban safety concern. The rapid increase in motorized vehicles, combined with the expansion of transportation infrastructure, has intensified urban mobility challenges. The alarming number of accidents, fatalities, and injuries underscores the urgent need for a comprehensive analysis of the spatial factors influencing traffic accidents in the city. Understanding the relationship between urban spatial patterns and accident occurrences is essential for developing effective mitigation strategies. Therefore, this study aims to evaluate the spatial factors contributing to traffic accidents in Balikpapan City and explore potential solutions to enhance road safety.

2. RESEARCH REVIEW AND VARIABLES

Research variables represent the key elements of a study that are observed, measured, and analyzed. To achieve the research objectives, specific variables have been identified as essential for conducting a comprehensive analysis. These variables have been selected based on a literature review and adjusted to align with the conditions of the study area.

Table 2. Research Review

Researcher	Research Title	Research purposes	Research Variables	Analysis Method	Research result
Winayati, Fadrizal Lubis, Hendri Rahmad (2015)	The Influence of Land Use Development on Traffic Movement Attraction and Road Service Level in Riau Pekanbaru	aims to identify land use factors that have the greatest impact on vehicle traffic attraction as a result of the development of business areas on Jalan Riau Pekanbaru.	Independent variables consisting of (PDRB, population, area of shop buildings, area of hotel buildings, and area of mall buildings) Dependent variable	Multiple Linear Regression and Correlation Model Analysis	In 2015, the road's service level was F, meaning traffic was obstructed (stops, queues, and congestion). Free-flow speeds ranged between 22 and 25 mph, with a free-flow speed limit of 27 mph.
Basim Jrew, Majed Msallam, Shereen Khaled, Mohammad Abojaradeh (2017)	Analysis And Evaluation Of Traffic Accidents For Principle Urban Streets In Arbil City In Iraq	Aims to analyze and evaluate the causes of traffic accidents using statistical analysis techniques, and independent observation studies.	Number of injured victims Fatalities Property damage Total accidents	Predictive statistical models using the Statistical Package for Social Sciences (SPSS) program	Increasing number of segments on the road urban areas will in principle increase the total number of accidents and the amount of damage property. In addition, it was also found that the pedestrian crossing area was neglected by pedestrians and drivers do not give priority to pedestrians to crossing the

Researcher	Research Title	Research purposes	Research Variables	Analysis Method	Research result
					road, due to lack of traffic awareness by drivers and pedestrians
Deni Setiawan, Mayani Asima (2019)	Traffic Accident Risk Mapping on the Cipularang Toll Road Section	Aims to analyze traffic accident risk factors and conduct risk mapping on the Cipularang Toll Road section.	Traffic Accident Data on Cipularang Toll Road Factors Causing Traffic Accidents traffic accident location	Descriptive research method.	This study shows that in 2014, the very dangerous risk category experienced the highest traffic accidents. According to the toll road map, the West Padalarang KM.84–KM.120 Ram Jati Luhur section is the most vulnerable location for traffic accidents on the Cipularang Toll Road.
Handika Putra Pratama, Dedy Kurnia Sunaryo, Silvester Sari Sai (2020)	Accident Prone Area Analysis for Making Accident Prone Maps	Aiming to determine the level of accuracy of WorldView Imagery – 2 in identifying accident-causing parameters. Researchers use analysis.	Turning radius, facilities Crossing the road Railway crossing Clear visibility Road markings Traffic signs Type of land use.	Image interpretation and field survey methods and Geographic Information Systems (GIS)	The results of the study show that WorldView-2 imagery affects the vulnerability of traffic accidents well. The level of accuracy of parameter interpretation of 91.01% shows that the spatial model of the level of accident vulnerability works well because it is in accordance with accident data

Researcher	Research Title	Research purposes	Research Variables	Analysis Method	Research result
					from the police, where roads with This class is very vulnerable, vulnerable, and safe, with high accident and accident rates.
Patricia A'lvarez, Miguel A. Ferna´ndez, Alfonso Gordaliza, Alberto Mansilla, Aquilino Molinero (2020)	Geometric Design Factors of Roads Affecting Urban Runoff Accident Risk	Detecting risk factors for geometric road design that are characteristic of urban spillover accident locations	Type of intersection Radius of curvature sidewalk width traffic lane width Number of lanes for traffic in the same direction Traffic directions Length of previous straight section Distance to the previous traffic light, slope, and finally, priority setting	Logistic regression model	urban location that have a higher probability of causing a spillover accident are: Curves with a "traffic lane width" of more than 3.75 meters, (the probability of a run-off accident on a curve with a lane width wider than 3.75 meters is more than six times higher) or when "there are traffic lights to regulate traffic" or when "there are traffic lights to regulate traffic".75m is more than six times higher).
Sri Hidayat, Syafri, Syahriar Tato (2021)	The Influence of Land Use and Traffic Performance On Urban Climate In Peri-Urban Areas	to analyze land use relationships and traffic performance on urban climate	1. Land Use 2.Traffic Performance 3.Climate Conditions	soft modeling	The results of the study can be concluded that land use has a significant impact on conditions the

Researcher	Research Title	Research purposes	Research Variables	Analysis Method	Research result
	Mamminasata				Hertasning-Tun Abdul Razak road corridor

The following table outlines the research variables, their indicators, and operational definitions:

Table 3. Research Variables

Target	Indicator	Variables	Operational Definition
Traffic Accident Characteristics	Type of Accident	Severity Level	Accident fatality rates are classified into: (1) Minor (2) Moderate (3) Severe
		Number of Accidents	Frequency of traffic accidents
		Number of Victims	Total number of victims involved in accidents
		Vehicle Type	Types of vehicles involved in accidents: (1) LV – Light Vehicle (2) HV – Heavy Vehicle (3) MC – Motorcycle (4) NM – Non-Motorized Vehicle
Factors Contributing to Accidents	Accident Causes	Land Use	Dominant land use in accident-prone areas: (1) Commercial (2) Industrial (3) Office Areas (4) Public Service Facilities (SPU) (5) Residential (6) Green Open Space
		Road Conditions	Road conditions contributing to accidents: (1) Damaged roads (2) Potholes (3) Slippery surfaces (4) Obstructed view (5) Poor lighting (6) Missing road markings (7) Lack of signage (8) Damaged road markings (9) Broken signs (10) Sharp turns (11) Steep inclines
		Human Behavior	Human-related factors leading to accidents: (1) Carelessness (2) Disobedience to traffic rules (3) Speeding (4) Failure to maintain safe distance (5) Health issues (6) Psychological stress (7) Medication use (8) Drunk driving (9) Use of addictive substances
Accident-Prone Area Analysis and Mapping	Accident Location	Coordinate Points	Geographical coordinates of accident locations
	Land Use	Dominant Land Use	Classification of land use in accident-prone areas: (1) Commercial (2) Industrial (3) Office Areas (4) Public Service Facilities (SPU) (5) Residential (6) Green Open Space

	Road Classification	Road Function	Type of road where the accident occurred: (1) Arterial (2) Collector (3) Local/Environmental
		Road Status	Administrative classification of the road: (1) National (2) Provincial (3) City Road
	Traffic Accident Frequency	Number of Accidents	Total number of accidents recorded in a specific area

3. METHOD

This study employs spatial mapping analysis using Geographic Information System (GIS) software, specifically ArcGIS, to illustrate the distribution and severity of traffic accidents. The analysis incorporates *Getis-Ord Gi statistics**, a hotspot analysis tool that identifies spatial clustering within the dataset. This method detects accident-prone areas by analyzing locations with a high concentration of incidents.

The *Getis-Ord Gi statistics** technique works by integrating observation values from neighboring locations to determine spatial patterns and clustering trends, ultimately identifying accident hotspots. These hotspots indicate areas where traffic accidents occur with significantly higher frequency compared to surrounding locations.

Additionally, descriptive statistical analysis is applied to summarize, analyze, and interpret accident data. This method involves collecting, organizing, and presenting numerical data in graphical form to facilitate interpretation. Through descriptive statistics, accident frequencies are analyzed using tables, graphs, and spatial frequency maps to illustrate trends and patterns in traffic incidents.

3.1 Analyzing the Characteristics of Traffic Accidents in Balikpapan City

To examine the characteristics of traffic accidents in Balikpapan City, descriptive statistical analysis is utilized. This method provides a comprehensive overview of traffic accident trends and patterns. The study presents data using tables, graphs, and spatial frequency maps for each variable to enhance visualization and interpretation.

- Frequency Tables: Display the number of occurrences for each category within a variable.
- Histogram Graphs: Represent the frequency distribution of variables visually, making it easier to identify trends and patterns.
- Spatial Frequency Maps: Illustrate accident density across different locations, highlighting high-risk areas.

The following formula is used to calculate and generate frequency graphs for each variable:

This statistical approach enables a clearer understanding of traffic accident characteristics, contributing to better decision-making in accident prevention and urban planning.

Frequency : $F = \frac{n}{N}$

Percentage : $\% = \frac{n}{N} \times 100\%$

Description: n = Number of accidents in a certain category

N = Total number of observations

The frequency analysis of each variable in traffic accidents includes:

- Severity Level: Measures the number of accidents categorized by severity—light, moderate, or severe.
- Vehicle Type: Determines the frequency of accidents involving different vehicle types, classified as LV (Light Vehicle), HV (Heavy Vehicle), MC (Motorcycle), and NM (Non-motorized Vehicle).
- Land Use: Analyzes the frequency of accidents based on the dominant land use in the surrounding area.
- Road Classification: Evaluates the number of accidents occurring within different road classifications.
- Road Conditions: Assesses the frequency of accidents based on the condition of the road at the time of the incident.
- Human Behavior: Identifies the number of accidents attributed to specific human behaviors that contribute to crashes.

3.2. Analyzing Spatial Patterns of Traffic Accident Frequency in Balikpapan City by using *Hot Spot Analysis Using Getis-Ord Gi Statistics**

Hot Spot Analysis is a spatial statistical method used to identify clusters of high and low values in a dataset. This method calculates Getis-Ord Gi* statistics for each feature within the dataset, producing Z-scores and P-values that indicate where statistically significant spatial clusters exist. The primary objective of this analysis is to uncover the spatial structure and patterns of traffic accidents in Balikpapan City, allowing for meaningful insights. ArcGIS software is utilized for spatial modeling, where the Getis-Ord Gi* statistic identifies hot spots (high accident density areas) and cold spots (low accident density areas) by analyzing Z-scores and P-values:

- Z-score: A measure of standard deviation, determining the intensity and statistical significance of clustering.
    - A high positive Z-score indicates a hot spot, where a location with a high number of accidents is surrounded by other high-accident areas.
    - A low negative Z-score indicates a cold spot, where a location with a low number of accidents is surrounded by other low-accident areas.
- P-value: Represents the probability level, confirming the statistical significance of the Z-score and determining whether an area is a hot spot or cold spot with confidence.

For a location to be classified as a statistically significant hot spot, it must have a high accident frequency and be surrounded by other locations with similarly high accident rates. Conversely, a cold spot is formed in areas with consistently low accident frequencies.

Hot Spot Analysis using Getis-Ord Gi* is a crucial part of the Mapping Clusters Toolset, which helps identify statistically significant spatial clusters of high (hot spots) and low (cold spots) accident frequencies (ESRI, 2024).

$$G_i^* = \frac{\sum_{j=1}^{n} \omega_{i,j} x_j - \bar{X} \sum_{j=1}^{n} \omega_{i,j}}{S \sqrt{\frac{[n \sum_{j=1}^{n} \omega_{i,j}^2 - (\sum_{j=1}^{n} \omega_{i,j})^2]}{n-1}}}$$

Information :

- G(i): The Getis-Ord Gi* value for accident point *i*, representing the clustering intensity of traffic accidents at that location.
- X_j: The accident frequency value at point *j* (a neighboring accident location).
- X: The average accident frequency across all analyzed locations.

- w_ij: The spatial weight between accident points i and j, indicating their spatial relationship.
- S: The standard deviation of accident frequency, measuring variability across locations.
- n: The total number of accident points included in the analysis.
- i: A specific accident point representing a unique location where an accident occurred.
- j: A neighboring accident point surrounding i, influencing the spatial clustering pattern.

3.3. Analyzing the Influence of Spatial Factors on Traffic Accidents in Balikpapan City

This analysis aims to identify spatial categories that exhibit significant differences compared to others. It builds upon the results of the hotspot analysis, which categorizes accident-prone areas based on spatial clustering patterns. After spatial modeling reveals the structure and distribution of traffic accidents, further exploration is conducted to examine both spatial and non-spatial factors influencing accident occurrences. This helps to better understand the relationship between accident hotspots and surrounding land use patterns. To assess these relationships, a simple regression analysis is employed. This method determines how well an independent variable predicts a dependent variable. In cases of linear relationships, changes in variable X correspond to proportional changes in variable Y. However, in nonlinear relationships, changes in X do not result in proportional changes in Y. In this study, accident points categorized as hotspots serve as the dependent variable (Y), while land use acts as the independent variable (X) to evaluate their influence on accident occurrences.

$$Y= a+bX+eY= a+bX+e$$

Information :

Y is the dependent variable
X is the independent variable ,
a is the intercept (constant),
b is the regression coefficient, which shows the change in Y for every one unit change in X.
e is the error (difference between the actual and predicted values)

4. DISCUSSION

4.1. Analyzing the Characteristics of Traffic Accidents in Balikpapan City

Traffic accident data from the Traffic Police and Balikpapan Resort Police from 2020 to 2023 were analyzed to identify accident characteristics in Balikpapan City. A total of 382 traffic accidents were recorded during this period, resulting in 428 fatalities, 45 serious injuries, and 182 minor injuries. Descriptive statistical analysis was conducted on each variable to determine its significance in accident occurrences, as detailed below.

a. Accident Characteristics by Severity

An analysis of accident severity revealed a significant distribution of casualties: Fatalities accounted for 53% of all accident victims, indicating that more than half of the total victims lost their lives. This highlights the serious consequences of traffic accidents in the study area. Minor injuries were also high, comprising 48% of victims. While these injuries were not life-threatening, they still indicate widespread physical trauma. Serious injuries accounted for 12% of victims, further underscoring the severity of traffic accidents in Balikpapan. These

findings suggest that traffic accidents in Balikpapan often result in significant injury or death, emphasizing the need for improved safety measures.

b. Accident Characteristics by Vehicle Type

The analysis of vehicle types involved in accidents highlights significant differences in accident frequency across different vehicle categories: Motorcycles were involved in 375 incidents (93%), making them the most high-risk vehicle type. This finding suggests that motorcycle riders are particularly vulnerable to accidents. Heavy vehicles were involved in 96 accidents (25%), indicating a considerable presence of large trucks and commercial vehicles in accident data. Light vehicles (such as private cars) had the lowest accident frequency, with 62 incidents (16%) of the total accidents recorded. These results confirm that motorcycles carry a disproportionately high risk of involvement in traffic accidents, necessitating targeted safety interventions for motorcyclists.

c. Accident Characteristics by Human Behavior

Driver behavior is a major contributing factor to accidents in Balikpapan: 43% of accidents were caused by violations of traffic laws, such as ignoring signs, running red lights, and disregarding road rules. 10% were due to lack of attentiveness, often caused by distractions such as mobile phone use or in-car activities. 7% resulted from speeding, which reduces vehicle control and increases accident severity. 5% were caused by driving under the influence of alcohol, impairing motor skills and decision-making, thus increasing the likelihood of severe accidents. 3% were attributed to unsafe driving practices, including failure to maintain a safe distance, psychological stress, and the influence of addictive substances. These findings indicate that most accidents could be prevented through better enforcement of traffic regulations, enhanced driver education, and awareness campaigns on the dangers of reckless driving.

d. Accident Characteristics by Land Use

Traffic accidents in Balikpapan occur across diverse land-use areas, each presenting unique risk factors: Residential areas experience frequent accidents due to high population density and increased interaction between vehicles and pedestrians. Industrial zones pose accident risks due to the movement of heavy vehicles, logistics operations, and large trucks. Green open spaces, plantations, and urban forests also see accidents, often due to poorly maintained roads and challenging driving conditions. Understanding the relationship between land use and accident frequency can help develop targeted safety strategies for different areas.

e. Accident Characteristics by Road Classification

The analysis also examined the distribution of accidents across different road types: Arterial roads and collector roads had the highest accident rates, as these roads serve high-capacity traffic and long-distance travel. Local roads and neighborhood roads recorded fewer accidents, as they cater to local traffic with lower vehicle volumes. These findings suggest that arterial and collector roads require enhanced safety measures, such as better signage, improved lighting, and stricter speed control to reduce accident risks.

The statistical analysis of traffic accidents in Balikpapan City highlights several critical insights: High fatality rates indicate the severe impact of traffic accidents. Motorcycles are the most accident-prone vehicle type, requiring targeted safety interventions. Human behavior plays a significant role in accidents, particularly traffic violations and inattentive driving. Land use affects accident distribution, with residential and industrial areas experiencing the most incidents. Arterial and collector roads are high-risk zones due to heavy traffic flow and long-distance travel.By addressing these key issues through policy changes, infrastructure improvements, and public awareness campaigns, authorities can work toward reducing traffic accidents and improving road safety in Balikpapan City.

Fig 1. Road Network With the Most Accident Points in Balikpapan City

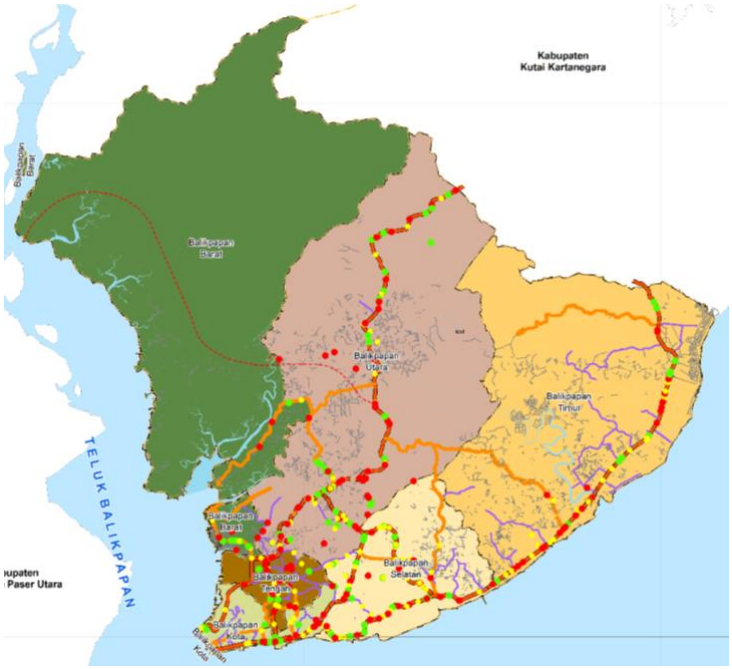

Fig 2. Accident Points Based on Severity Level in Balikpapan City

4.2. Analyzing Spatial Patterns of Traffic Accident Frequency in Balikpapan City

The analysis of spatial patterns of traffic accident frequency in Balikpapan City aims to identify hotspot and coldspot areas where accidents frequently occur. Using Getis-Ord Gi* statistical analysis in ArcGIS software, spatial modeling is conducted to map areas with high and low accident densities based on Z-scores and P-values. Z-score: Represents the standard deviation in the analysis, indicating the statistical significance of accident intensity. Higher Z-scores suggest more concentrated accident clusters, forming hotspots. P-value: Represents the probability that the Z-score is statistically significant. It determines whether an area qualifies as a hotspot or a coldspot. A hotspot forms when an area has a high number of accidents and is surrounded by other areas with similarly high accident frequencies.

Conversely, a coldspot forms when an area has a low number of accidents and is surrounded by other areas with similarly low accident frequencies.

a. Accident Clustering and Spatial Analysis

ICount (Item Count): This refers to the total number of accident points analyzed. In this study, accident points were grouped based on proximity, with a 200-meter radius used to identify clusters. The highest layer of grouping contained 13, 9, 8, 7, 6, 5, and 4 accident points, forming significant clusters. Z-score distribution: Areas with high positive Z-scores indicate hotspots, while areas with low negative Z-scores indicate coldspots. NNeighbors (Number of Neighbors): This refers to the number of surrounding accident points considered in the statistical calculations. The study identified 222 neighboring accident points, with the largest cluster containing 18 neighboring points, while the smallest contained 2 neighboring points.

In some cases, the number of neighboring accident points in a cluster did not reach the 200-meter radius, indicating localized accident hotspots within smaller areas.

b. Hotspot and Coldspot Distribution in Balikpapan City

The results of the spatial analysis identified the most critical accident hotspots in the following districts: North Balikpapan District (West), Balikpapan City District, Central Balikpapan District, South Balikpapan District.

These hotspot areas are visually represented in dark red on the spatial map, indicating high accident intensity. Meanwhile, coldspot areas—where accidents occur less frequently—are depicted in blue on the spatial map. The spatial analysis of traffic accidents in Balikpapan City provides valuable insights into high-risk areas, allowing for: Targeted traffic safety interventions in hotspot areas. Improved urban planning to mitigate accident risks. Strategic law enforcement efforts in accident-prone zones. By leveraging spatial modeling techniques, policymakers and transportation authorities can develop data-driven solutions to enhance road safety and reduce traffic accidents in Balikpapan City.

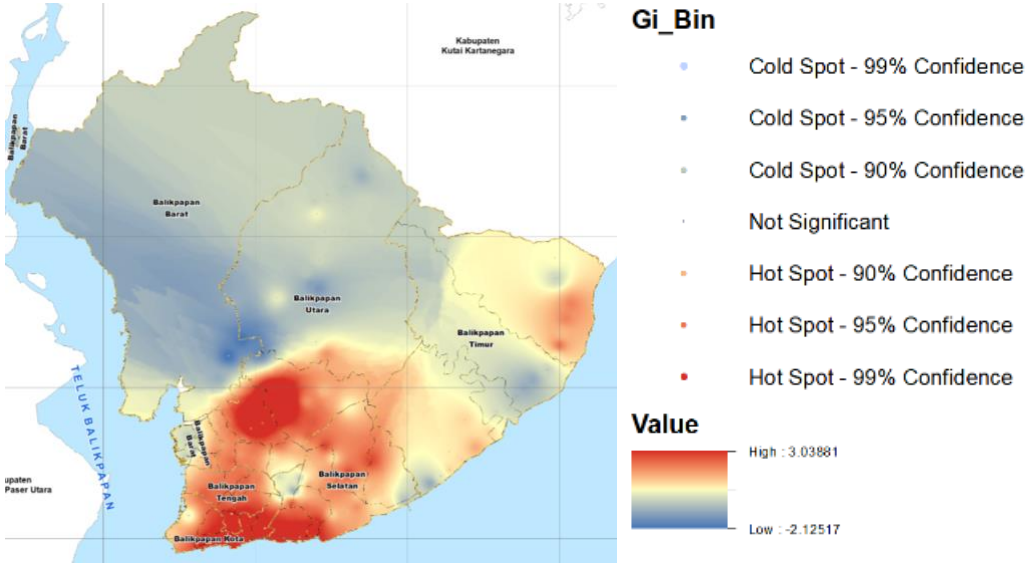

Fig 3. Hotspot Analysis in Balikpapan City

4.3. Analyzing the Influence of Spatial Factors on Traffic Accidents in Balikpapan City.

This analysis is a further analysis that aims to determine the category of variables that have significant differences based on the output of the hotspot analysis of accident points. Each of these accident points contains accident factor variables related to land use. Regression analysis is carried out according to the number of hotspot results in accidents, as well as land use variables, based on land use classes.

Variables :
Dependent (y): results of Hotspot analysis , accident points included in hot spots.
Independent (x) : Land use variable
Based on the results of the regression analysis displayed, it can be interpreted as follows:

Tabel 4. Summary Output Results of Regression Analysis

Regression Statistics	
Multiple R	0.191888249
R Square	0.0368211
Adjusted R Square	0.032299134
Standard Error	4.070915846
Observations	215

The multiple correlation coefficient value is 0.191888249, which indicates a correlation, or relationship between the independent variable (land use) and the dependent variable (Hotspot analysis results , accident points included in the hot spot) .
(R-Square) is 0.0368211, meaning that only 3.68% of the variation in the dependent variable (hotspot analysis results , accident points included in the hot spot) , can be explained by the independent variable (land use) in this regression model. The remaining 96.32% is explained by other factors outside the model.

Table 5. Anova Results Regression Analysis Output

	df	SS	MS	F	Significance F
Regression	1	134.9440232	134,944	8.142718	0.004749975

significance value of F is 0.004749975, which is smaller than the significance level of 0.05. The null hypothesis (H0) which states that X does not affect Y is rejected, because the number <0.05. So it can be concluded that the regression model is statistically significant at a significance level of 5%. This means that the independent variables in this model have a significant influence on the dependent variable. This shows that the overall regression model is significant and there is at least one independent variable (land use) that has a significant influence on the dependent variable of the accident hotspot area in Balikpapan City.

Table 6. Correlation Analysis Results

	ICOUNT	GiZScore	GiPValue	Neighbors	ID_DATE
ICOUNT	1				
GiZScore	0.4181396	1			
GiPValue	-0.01423425	-0.160572632	1		
Neighbors	0.15567843	0.437638362	0.049651	1	
ID_DATE	-0.11776303	-0.185143987	0.123477	-0.19189	1

Impact of Spatial Factors on Traffic Accidents in Balikpapan City: Regression Analysis Results
The regression analysis results indicate a negative correlation between the independent variable (land use) and the dependent variable (accident hotspots identified through spatial analysis). This negative relationship suggests that as certain types of land use increase, the number of accident hotspots decreases, and vice versa. Among the land use categories

analyzed, Green Open Space (RTH) (ID_TGL1) was found to have a significant impact on accident occurrence. The findings suggest that: An increase in Green Open Space (RTH) correlates with a decrease in accident frequency. Conversely, a reduction in Green Open Space is associated with a higher number of accidents. This indicates that areas with more extensive green spaces and lower-density land use tend to experience fewer traffic accidents, whereas denser, high-activity zones see a higher accident rate. For urban planning Implications, the study highlights the critical role of urban green spaces in enhancing traffic safety. Expanding Green Open Spaces (RTH) could be an effective strategy for reducing accidents by: Minimizing traffic congestion in urban areas. Providing safer road environments with better visibility and pedestrian infrastructure. Encouraging alternative transportation modes such as walking and cycling, which may reduce vehicle-related accidents.

5. CONCLUSION

Based on the findings of this study, the following recommendations are proposed for policymakers and stakeholders in Balikpapan City: Further research is required to examine in greater depth how vehicle speed influences accident rates, particularly across different road types and varying traffic conditions. Understanding this relationship will help develop more effective speed management strategies. A comprehensive study should focus on road user behavior, including lane discipline and awareness of traffic regulations. Identifying behavioral patterns that contribute to accidents can provide insights for targeted interventions aimed at improving road safety. Despite careful research efforts, certain limitations were unavoidable during this study. One key challenge was restricted access to police data, as law enforcement agencies enforce strict confidentiality protocols to protect the integrity of investigations and safeguard individuals' privacy. This limitation may have impacted the depth of analysis in some areas. Future research on traffic accidents in Balikpapan City should integrate both spatial and non-spatial analyses to develop a more comprehensive understanding of accident patterns. Additionally, active collaboration with various stakeholders—including local government authorities, community representatives, and non-governmental organizations—will enhance the quality of research findings and support the effective implementation of safety measures.

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