Spatial Distribution and Cluster Analysis of Road Traffic Accidents in Khon Kaen Municipality, Thailand

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Abstract

This study examines the spatial distribution and cluster analysis of road traffic accidents (RTAs) within Khon Kaen Municipality, Thailand, focusing on the top ten intersections with the highest RTAs. The analysis incorporates general information on RTAs, including gender, age group, type of vehicles involved, group of victims, and the time of day when the accidents occurred. Analyzing data on RTAs, we found that the majority of incidents occurred among males aged 21-30 years, with drivers being the most affected group and motorcycle accidents being the primary cause. Notably, RTAs peaked between midnight and 4:00 AM, potentially correlated with late-night activities. Global Moran's I as well as Anselin local Moran's I were adopted in the cluster analysis to identify hotspots, coldspots, and outliers among the intersections. Examination of RTA hotspots revealed concentration along major roads, particularly Highway No. 2 and Sricharn Road, suggesting the importance of road infrastructure in accident prevalence. Utilizing Anselin's Local Moran's I analysis, we identified a spatially random distribution of RTAs, indicating a lack of distinct spatial patterns or clustering. These findings provide valuable insights for policymakers and authorities to implement evidence-based measures aimed at enhancing road safety within and beyond Khon Kaen Municipality.

Keywords: Cluster Analysis, Intersection Accident, Muang Khon Kaen, RTA, Road Section Accident

1. Introduction

Traffic accidents pose a significant global health challenge, resulting in a substantial number of deaths and injuries. According to the World Health Organization (WHO), annually, 1.3 million people worldwide succumb to traffic accidents, with an additional 20-50 million individuals sustaining injuries or disabilities [1]. In 2015, Thailand ranked as the country with the second-highest rate of road accidents globally, experiencing a death rate of 36.2 per 100,000 population [2]. From 2011 to 2021, Thailand witnessed 223,545 deaths due to traffic accidents, a figure notably higher than the WHO's goal of 10 deaths per 100,000 population. This alarming statistic underscores the severity of the road safety situation in Thailand, contributing significantly to the overall global burden of road traffic accidents.

Traffic accidents at junctions and intersections are a significant concern worldwide, posing substantial risks to road users and challenging public safety efforts. In Thailand, like many other countries, these locations are particularly prone to traffic incidents due to complex road geometries, varying traffic flows, and behavioral factors. Among the provinces in Thailand, Khon Kaen stands out as one of the regions with notable traffic congestion and accident rates. The mortality rate from road accidents in the province has exhibited a notable increase, especially following the decline of the COVID-19 pandemic situation in 2021, as illustrated in Figure 1.

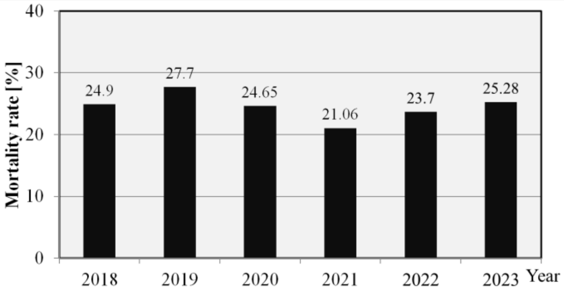


Figure 1: Road accident mortality rate in Khon Kaen province, Thailand [3]

In order to provide the information for decision makers and concerned authorities, the accident rate as well as the mortality rate should be analyzed. Geographic Information Systems (GIS) have emerged as indispensable tools in understanding and addressing traffic-related issues, offering spatial analysis capabilities that facilitate insightful decision-making processes. By integrating spatial data with accident records, GIS enables researchers and policymakers to identify high-risk areas, discern underlying patterns, and develop targeted interventions to enhance road safety. GIS has been adopted in several researches about road accident analysis. For instance, the impact of road intersection geometry, traffic volume, and traffic light waiting time on road accidents was investigated using least squares and spatial analysis. It identifies high-risk areas at junctions within the study area in Malaysia [4]. The identification of highway accident hotspots in Nakhon Pathom, Thailand, utilized cluster analysis techniques, kernel density estimation, and spatial autocorrelation analysis. The findings revealed that high-risk areas predominantly occurred along major roads characterized by heavy traffic flow and dense population concentrations [5]. Getis Ord Gi* was adopted in identifying road accident hot spots in Salangor, Malaysia, the relationship between road geometries and road accidental areas was also investigated.

The locations of road accident hotspots were visualized on a map. The results revealed that the majority of accidents occurred most frequently at T-intersections compared to other types of intersections in the study area [6]. In Geographic Information Systems (GIS), kernel density estimation (KDE) is a spatial analysis technique used to estimate the density of point features across a geographic area. It works by calculating the density of points within a defined search radius or kernel around each location on a grid. KDE is useful for identifying hotspots or areas of high point density, such as crime-prone areas, wildlife habitats, or concentrations of road accidents [7]. Speeding and insufficient awareness of driver safety and driving skills are recognized as significant contributors to traffic accidents in Thailand. Given the imperative for road safety enhancement, particularly at high-risk sites, the identification of black spots becomes crucial. Black spots denote intersections or road segments characterized by an unusually high frequency of traffic accidents [8] and [9].

According to previous studies on road accident investigation using GIS, it is obvious that road accident investigation utilizing GIS is paramount for understanding and addressing road safety challenges comprehensively. GIS enables spatial analysis, allowing for the identification of patterns and hotspots of accidents within a geographic area. By visually representing accident data on maps, GIS helps authorities recognize where accidents occur frequently and the spatial relationship between accidents and various factors such as road geometry, traffic flow, and environmental conditions [10]. Furthermore, GIS aids in pinpointing high-risk locations or black spots where accidents are more prevalent [11] . By analyzing historical accident data, GIS assists in prioritizing resources for targeted intervention and road safety enhancement measures [12]. Moreover, GIS facilitates the integration of diverse datasets, including road infrastructure, traffic volume, weather conditions, and driver behavior data. Through spatial analysis, GIS helps identify contributing factors to accidents such as poorly designed intersections, inadequate signage, speeding, or impaired visibility due to environmental factors [13].

Additionally, GIS provides decision support tools for policymakers, transportation planners, and law enforcement agencies. By visualizing spatial data and analysis results, GIS assists stakeholders in making informed decisions regarding road infrastructure improvements, traffic management strategies, enforcement efforts, and public awareness campaigns aimed at reducing accidents and enhancing road safety [14]. Furthermore, GIS enables the evaluation of the effectiveness of road safety interventions and mitigation measures [15]. By comparing accident data before and after the implementation of interventions, GIS helps assess the impact of these measures on accident rates and identifies areas for further improvement. Finally, GIS facilitates predictive modeling of road accidents, enabling the forecasting of future accident risk based on historical data and various predictive factors.

This proactive approach allows authorities to implement preventive measures and allocate resources proactively to mitigate potential risks and reduce the likelihood of accidents occurring in the future [16] and [17]. Overall, road accident investigation using GIS provides valuable insights into spatial patterns, contributing factors, and high-risk locations of accidents, facilitating evidence-based decision-making, targeted interventions, and proactive road safety management strategies [18]. This study aims to investigate the spatial patterns and contributing factors of traffic accidents at junctions and intersections within Khon Kaen Province, Thailand, employing a GIS-based analytical framework.

Through the utilization of geospatial techniques, such as spatial clustering analysis, hotspot identification, and proximity analysis, this study seeks to elucidate the spatial distribution of accidents and explore the underlying factors influencing their occurrence. Understanding the spatial dynamics of traffic accidents in Khon Kaen Province holds paramount importance for transportation planners, law enforcement agencies, and policymakers. By uncovering spatial patterns and identifying high-risk zones, proactive measures can be devised to mitigate accident risks, optimize traffic flow, and improve overall road safety. Furthermore, Khon Kaen's significance as a transportation nexus connecting northeastern Thailand with other regions further underscores the importance of road safety management and accident investigation in the province. Identifying high-risk areas, understanding contributing factors, and implementing targeted interventions can enhance road safety not only within Khon Kaen but also along critical transportation corridors linking the province to neighboring regions.

In conclusion, Khon Kaen, Thailand, offers a compelling setting for road accident investigation using GIS, given its diverse road network, traffic dynamics, demographic characteristics, and regional significance. Conducting comprehensive spatial analysis in Khon Kaen can provide valuable insights into road safety challenges and facilitate evidence-based decision-making for enhancing road safety measures in the province and beyond.

2. Study Area

Khon Kaen, Thailand, serves as an ideal study area for road accident investigation using GIS due to several compelling reasons. Situated in the northeastern region of Thailand, Khon Kaen is one of the largest and most populous provinces in the country, making it a significant transportation hub with extensive road networks and diverse traffic patterns. Khon Kaen's status as a populous province with high levels of urbanization and economic activity results in significant vehicular traffic volume across its road network. The bustling urban centers, industrial zones, and agricultural areas contribute to varied traffic conditions, ranging from congested city streets to rural highways, presenting a diverse range of road safety challenges [19].

Khon Kaen province is located in Khorat plateau, with elevation of approximately 167 m. Geographically, the province is situated at latitude of 16°26′48″N and longitude of 102° 49′ 58″E [20] as illustrates in Figure 2. The province is bisected by Highway No.2 or Mittraphap (Friendship) highway which is one of the four primary highways of Thailand [21].

3. Data and Methodology

3.1 Data Used

This cross-sectional analytical study examines individuals injured in traffic accidents at the ten intersections with the highest number of injuries annually over a span of 15 years within Muang Khon Kaen Municipality, covering the period from January 1, 2007, to December 31, 2021. Data were sourced from the Trauma and Critical Care Center of Khon Kaen Hospital, incorporating geographic information for accident locations and injury data from the injury surveillance system. The locations of the top ten intersections with the highest numbers of the accident rate depicts in Figure 3. The statistics of the road traffic accident (RTA) at 10 intersections in Muang Khon Kaen city accumulated from 2007 to 2021 illustrates in Table 1.

3.2 Methodology

The incidences of road traffic accidents (RTA) at 10 intersections were depicted through maps. Subsequently, the presence of spatial autocorrelation was assessed using Global Moran’s I. Following this, hotspot locations were identified using the Anselin Local Moran’s I approach. Additionally, factors associated with RTA, including alcohol and drug use, failure to wear helmets or fasten seatbelts, and cellphone usage, were analyzed to explore correlations between these factors and RTA occurrences. The research methodology is illustrated in Figure 4.

3.2.1 Global Moran’s I

Global Moran's I is a statistic used in spatial analysis to assess the degree of spatial autocorrelation within a dataset. It measures the overall similarity or dissimilarity of attribute values between neighboring features across an entire study area.

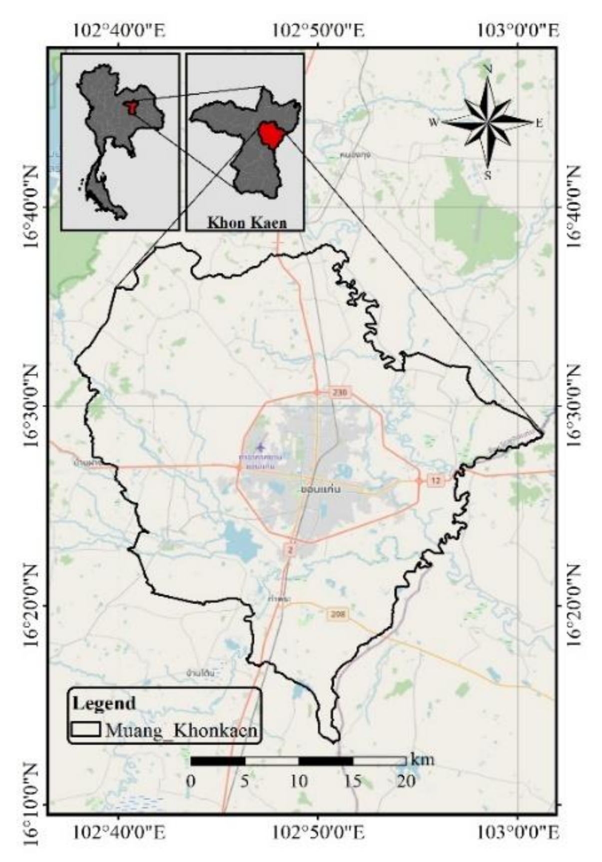


Figure 2: Muang Khon Kaen city, Khon Kaen, Thailand

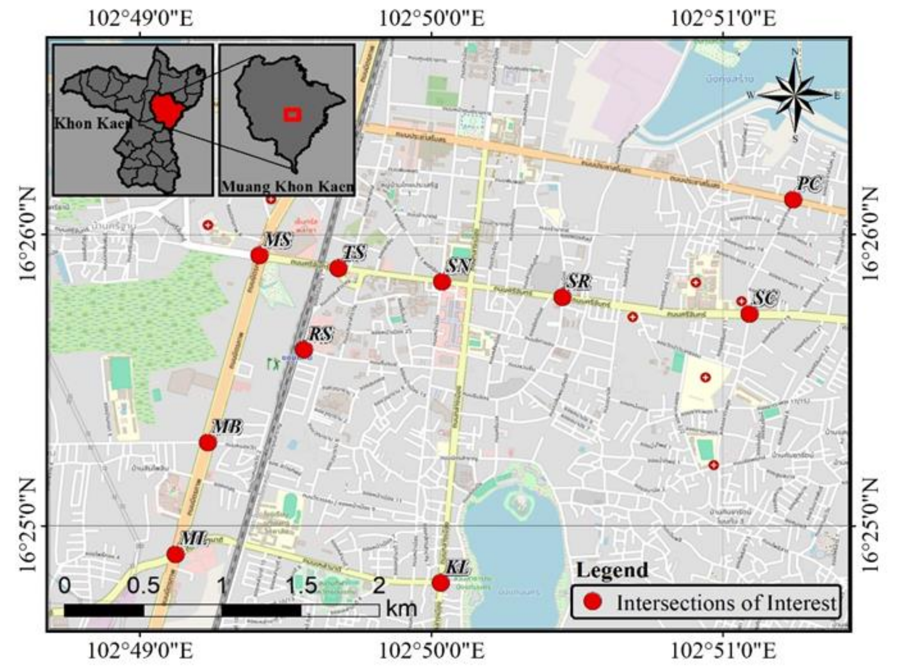


Figure 3: Locations of the ten intersections within Muang Khon Kaen city

Table 1: RTA statistics for accidents from 2007 to 2021 in Muang Khon Kaen city for various categories

General data	**Accidental numbers (%)**
Gender	
Male	2019 (60.9)
Female	1298 (39.1)
Age	
< 11	41 (1.3)
11-20	1030 (32.0)
21-30	1189 (36.9)
31-40	477 (14.8)
41-50	283 (8.8)
51-60	194 (6.0)
>60	8 (0.2)
Vehicle	
Bike	20 (0.6)
Motorcycle	3012 (94.1)
Tricycle	19 (0.6)
Sedan	59 (1.8)
Pick up	70 (2.2)
Big truck	3 (0.1)
Trailer	1 (0.03)
Minibus Bus	9 (0.3)
Taxi	1 (0.03)
Van	4 (0.1)
Injuries	
Pedestrian	115 (3.5)
Driver	2694 (81.4)
Passenger	496 (15.0)
Time	
8.01-12.00	459 (14.1)
12.01-16.00	461 (14.1)
16.01-20.00	615 (18.9)
20.01-24.00	599 (18.4)
00.01-04.00	731 (22.4)
04.01-08.00	396 (12.1)

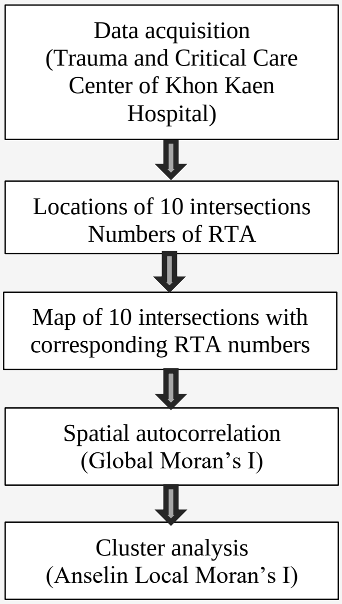


Figure 4: RTA cluster analysis in Muang Khon Kaen city workflow

The value of Moran's I ranges from -1 to 1, where positive values indicate positive spatial autocorrelation (similar values clustered together) and negative values indicate negative spatial autocorrelation (dissimilar values clustered together), while a value close to zero suggests spatial randomness. Global Moran's I is calculated by comparing the observed spatial distribution of attribute values to what would be expected under spatial randomness, providing insights into the spatial clustering or dispersion of features and helping to identify spatial patterns within the dataset. Global Moran's I can be determined from Equation 1 [22].

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j} z_i z_j}{S_0 \sum_{i=1}^{n} z_i^2}$$

Equation 1

Where:

I	is Global Moran's I
n	is the number of features
$w_{i,j}$	is spatial weight matrix elements
z_i	is the difference between the observation and its mean at location i
S_0	is the sum of all the weights

The sum of all the weights (S_0) is defined in Equation 2:

$$S_0 = \sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j}$$

Equation 2

The Spatial Autocorrelation (Global Moran's I) tool functions as an inferential statistic, requiring interpretation in relation to its null hypothesis. Regarding the Global Moran's I statistic, the null hypothesis posits that the attribute under examination is randomly distributed among the features within the study area. A statistically significant p-value indicates rejection of the null hypothesis.

3.2.2 Anselin local Moran's I

Anselin's Local Moran's I, a spatial autocorrelation statistic, extends Global Moran's I by providing localized insights into spatial clustering patterns within a dataset. While Global Moran's I assesses overall spatial autocorrelation across an entire study area, Local Moran's I examines spatial autocorrelation at the individual feature level. This allows for the identification of specific areas where similar values are clustered together or where dissimilar values are clustered together, offering a more nuanced understanding of spatial patterns. The computation of Local Moran's I involves comparing the attribute value of each feature to the average attribute value of its neighboring features. This comparison is performed for every feature in the dataset, resulting in a Local Moran's I value for each feature. The resulting Local Moran's I values are then categorized into four quadrants: High-High (HH), Low-Low (LL), High-Low (HL), and Low-High (LH). HH and LL represent areas of positive spatial autocorrelation where similar values cluster together, while HL and LH represent areas of negative spatial autocorrelation were dissimilar values cluster together.

4. Results and Discussion

4.1 General RTA

The data presents in Table 1 were transformed into chart format for the visualization and enhance the data comparison as depicts in Figure 5.

According to the results depicted in Figure 5, the rate of accidents can be characterized concerning the numbers of RTA classified by different scenarios as follows:

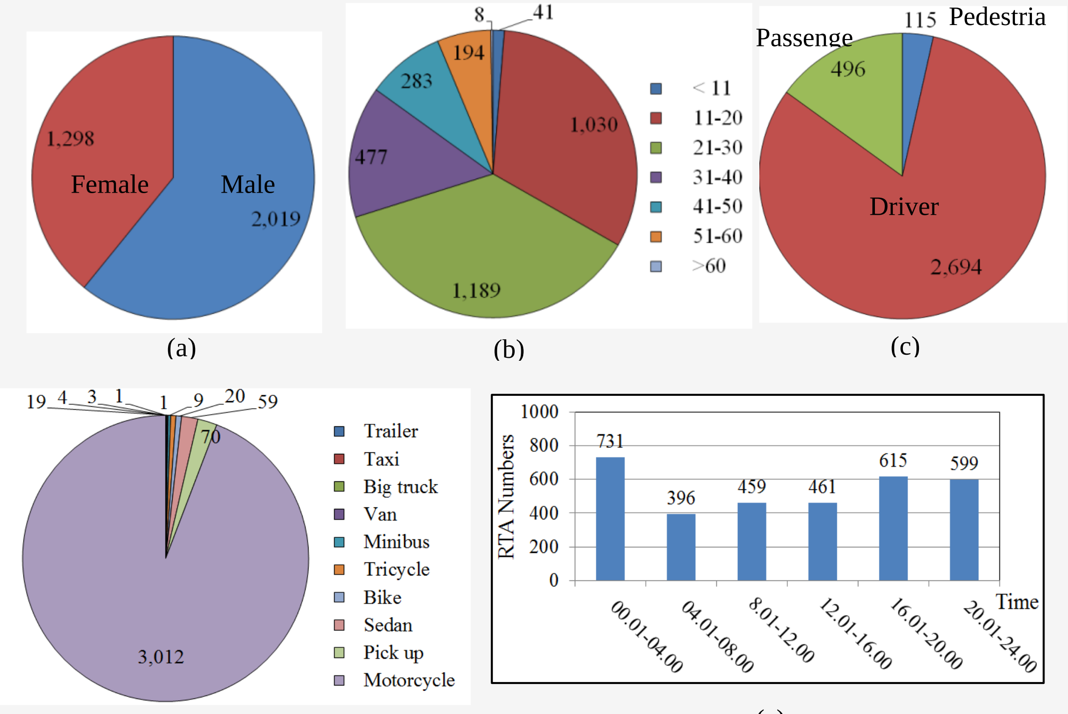
- *Gende*r: Approximately 60.9% of RTAs were found to occur in males, whereas 39.1% occurred in females (Figure 5(a)). This finding suggests that RTAs are more likely to occur in males. These results align with previous studies indicating that the accident rate among males is significantly higher than among females [23][24] and [25].
- *Age*: The age group of 21-30 years exhibited the highest incidence of RTAs, followed by 11-20 years, 31-40 years, 41-50 years, 51-60 years, <11 years, and >60 years, with RTA percentages of 36.9%, 32.0%, 14.8%, 8.8%, 6.0%, 1.3%, and 0.2%, respectively (Figure 5(b)). These findings are consistent with previous research indicating that the highest accident rate occurs among individuals aged 21-29 years. Moreover, crash rates were observed to be highest in the younger age groups, gradually declining with increasing age [26].
- *Injury group*: Most of the accidents occurred to drivers, followed by passengers and pedestrians (Figure 5(c)). It's evident that the number of drivers involved is significantly higher than that of the other groups. This suggests that drivers have a greater likelihood of being injured in RTAs compared to passengers and pedestrians. Therefore, to minimize the RTA rate, drivers should remain attentive while driving and adhere strictly to traffic regulations. This finding aligns with reports from the US, where the majority of RTA victims were identified as drivers [27].

- *Type of vehicles*: As per Figure 5(d), it's evident that approximately 94.1% of RTAs were predominantly caused by motorcycles, with other vehicle types showing negligible involvement. The rising trend in registered motorcycles in Thailand, increasing from around 19 million in 2013 to 21 million in 2020 [28], has contributed to the escalation of motorcycle accident rates. Motorcycles are a favored mode of transportation in Thailand, particularly among the younger demographic. Data from the Thai Road Accident Victims Protection Company reveals that motorcycle accidents account for over 85.2% of all accidents in Thailand [29].
- *Time of the day*: The highest RTA rate occurs between midnight and 4:00 AM, possibly attributed to the closure of nightlife venues in Thailand at 2:00 AM. It's plausible that individuals leaving these establishments, potentially intoxicated, contribute significantly to nighttime road accidents.

In summary, the analysis reveals that in Khon Kaen province, the majority of road traffic accidents (RTAs) were reported among males aged 21-30 years. Furthermore, the majority of RTA victims were drivers, with motorcycle accidents representing the primary cause. Notably, RTAs peaked between midnight and 4:00 AM, coinciding with the closing hours of nightlife venues, potentially indicating a correlation between late-night activities and heightened accident rates.

4.2 Numbers of RTA

The numbers of RTA at 10 intersections within the study area illustrates in Table 2 and Figure 6. It is evident that the top ten locations with the highest number of RTAs in the Muang Khon Kaen district are situated along major roads within the city, specifically Highway No. 2 (Mittraparp Highway) and Sricharn Road. The intersection with the highest RTA frequency was observed at Mittraparp-Bankok (MB), whereas the lowest RTA incidence was recorded at Prachasamosorn-Chatapadoong (PC). These findings suggest that RTA occurrences are more likely to be elevated in large junctions with wide roads and heavy traffic flow. Mittraparp Highway serves as a crucial transportation artery linking the central part of the country to Khon Kaen, thereby explaining the higher RTA rates predominantly observed at intersections along this highway.



(a) (b) (c)

(d) (e)

Figure 5: Numbers of RTA classified by (a) gender (b) age group (c) injured group (d) type of vehicle (e) time of the day

Table 2: Numbers of RTA in Muang Khon Kaen district

No.	Intersection	Abbreviation	RTA numbers (%)
1	Mitraparp-Bankok	MB	513 (15.5)
2	Mitraparp-Laonadee	ML	404 (12.2)
3	Sricharn-Chatapadoong	SC	434 (13.1)
4	Mitraparp-Sricharn	MS	337 (10.2)
5	Srichan-Robmuang	SR	241 (7.3)
6	Klangmuang-Laonadee	KL	190 (5.7)
7	Tedsabarn-Sricharn-Teparak roundabout	TS	133 (4.0)
8	Railway station roundabout	RS	196 (5.9)
9	Sricharn-Namuang	SN	136 (4.1)
10	Prachasamosorn-Chatapadoong	PC	88 (2.7)

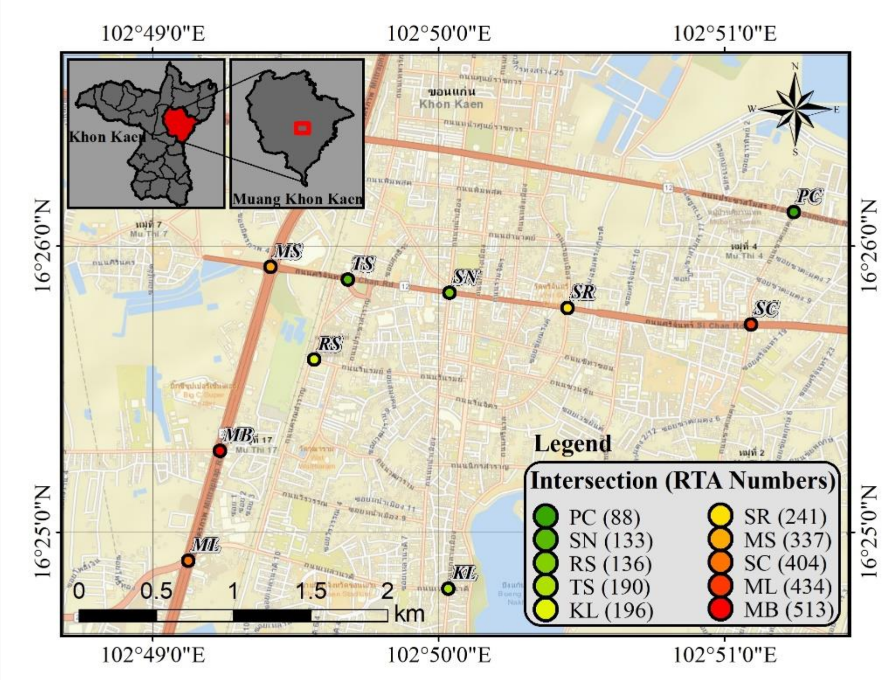


Figure 6: Intersections and the numbers of RTA

4.3 Global Moran's I

Global Moran's I is a statistical measure utilized in spatial analysis to evaluate the extent of spatial autocorrelation present within a dataset. In this study, the numbers of RTAs at 10 intersections within the study area were examined for spatial autocorrelation. The analysis revealed a Moran's index of -0.026, with corresponding z-score and p-value of 0.458 and 0.647, respectively (refer to Figure 8). These results indicate that no discernible pattern exists within the dataset, suggesting that the occurrences of RTAs at each intersection are random.

4.4 Anselin local Moran's I

In the previous section, it is evident that spatial autocorrelation does not exist within the dataset. Therefore, hot spots (HH) and cold spots (LL) of the RTAs cannot be identified in the study area. However, the outliers (HL and LH) pattern of the dataset can be explored using Anselin's local Moran's I.

Figure 9 reveals that neither clusters nor outliers were observed in any of the 10 intersections within the study area, as determined by Anselin's Local Moran's I analysis, it suggests that there is no statistically significant clustering or spatial patterns present. In other words, there are no areas where high values (hot spots) or low values (cold spots) of the variable of interest are clustered together in close proximity. Additionally, the absence of outliers (HL and LH) indicates that there are no individual data points with significantly different values compared to their neighboring areas.

Figure 7: Intersections of interest (a) MB (b) ML (c) SC (d) MS (e) SR (f) KL (g) TS (h) RS (i) SN and (j) PC

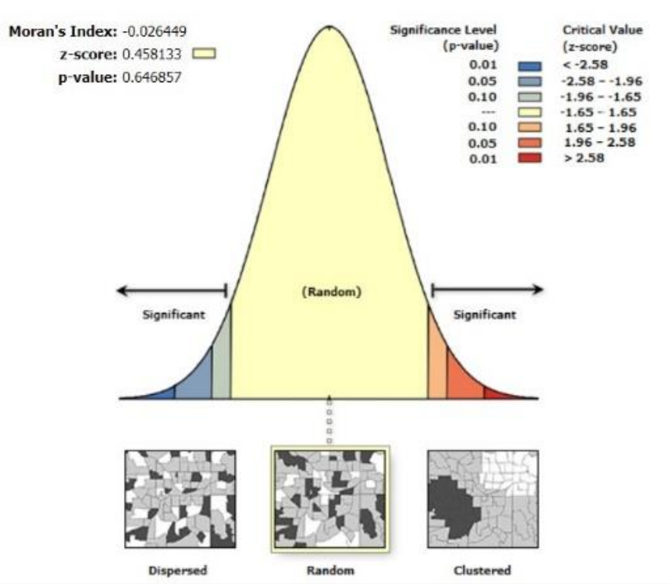


Figure 8: Global Moran’s I spatial autocorrelation

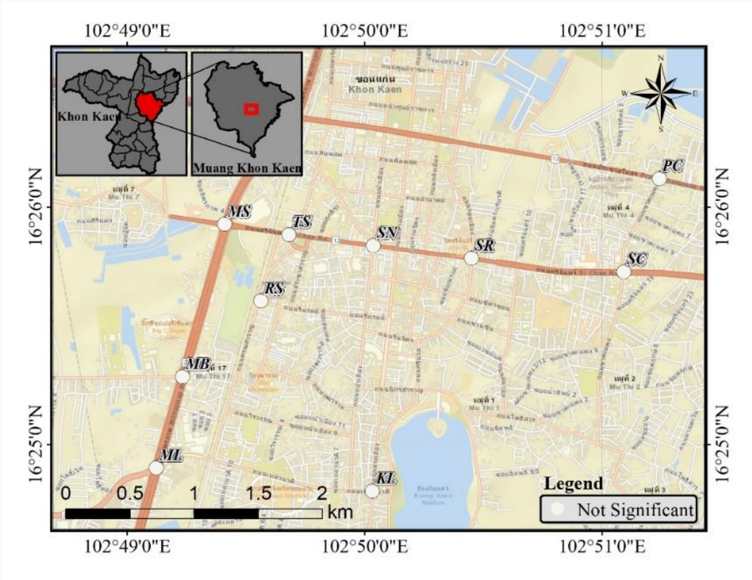


Figure 9: RTA cluster analysis

This outcome suggests a spatially random distribution of the variable being analyzed throughout the study area. The absence of hot spots, cold spots, and outliers in the dataset as identified by Anselin's Local Moran's I analysis signifies a spatially homogeneous distribution of the variable under investigation. This suggests that there are no localized areas within the study region where RTAs are consistently higher or lower than expected based on neighboring regions. Such uniformity in RTA occurrence across the study area may indicate a lack of distinct spatial patterns or factors influencing accident rates. Moreover, the absence of spatial clustering or outliers could be indicative of a well-distributed and evenly dispersed spatial process related to RTAs. It implies that factors contributing to accidents, such as road conditions, traffic density, and driver behavior, are evenly spread throughout the study area, without any discernible areas of heightened or diminished risk. This finding could have implications for policy-making and intervention strategies, suggesting that efforts to mitigate RTAs may need to be applied uniformly across the entire area rather than targeting specific hot spots or outlier regions.

5. Conclusion

In conclusion, the analysis indicates that in Khon Kaen province, the majority of road traffic accidents (RTAs) occurred among males aged 21-30 years. Moreover, most RTA victims were drivers, with motorcycle accidents being the primary cause. Significantly, RTAs peaked between midnight and 4:00 AM, aligning with the closing hours of nightlife venues, suggesting a potential correlation between late-night activities and increased accident rates.

The analysis reveals that the top ten locations with the highest number of RTAs in the Muang Khon Kaen district are concentrated along major roads, notably Highway No. 2 (Mittraparp Highway) and Sricharn Road. Notably, the intersection with the highest RTA frequency, Mittraparp-Bankok (MB), contrasts with the lowest RTA incidence recorded at Prachasamosorn-Chatapadoong (PC). These findings underscore the likelihood of elevated RTA occurrences at large junctions characterized by wide roads and heavy traffic flow. The prominence of Mittraparp Highway, serving as a vital transportation artery connecting the central part of the country to Khon Kaen, elucidates the higher RTA rates predominantly observed at intersections along this highway. Such insights are crucial for implementing targeted interventions aimed at mitigating the risk of accidents in high-traffic areas within the district.

The analysis conducted through Anselin's Local Moran's I indicates a lack of both clusters and outliers among the 10 intersections within the study area. This absence suggests that there is no statistically significant clustering or spatial patterns present in the data. Specifically, there are no localized areas where RTAs exhibit consistently higher (hot spots) or lower (cold spots) values in close proximity. Moreover, the absence of outliers (HL and LH) implies that there are no individual data points with significantly different values compared to their neighboring areas, further reinforcing a spatially random distribution of RTAs throughout the study area.

This spatially homogeneous distribution of RTAs across the study area suggests a lack of distinct spatial patterns or factors influencing accident rates. It indicates that factors contributing to accidents, such as road conditions, traffic density, and driver behavior, are evenly dispersed without any discernible areas of heightened or diminished risk. As a result, policy-making and intervention strategies aimed at mitigating RTAs may need to be uniformly applied across the entire area rather than targeting specific hot spots or outlier regions.

The decision-makers as well as concerning authorities could implement this study to minimize the RTA numbers within the study areas. Furthermore, this study can offer valuable insights into road safety challenges and support evidence-based decision-making to enhance road safety measures, both within the province and beyond.

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