Identification of Suburban Motorcycle Traffic Accident Hotspots Using GIS-based Spatial Analysis

J. Klaylee[1,2], P. Iamtrakul[1,2] and V. Sornlertlamvanich[3,4]

[1] Center of Excellence in Urban Mobility Research and Innovation, Faculty of Architecture and Planning, Thammasat University, Pathumthani, Thailand
[2] Faculty of Architecture and Planning, Thammasat University, Pathumthani, Thailand,
[3] Asia AI Institute (AAII), Faculty of Data Science, Musashino University, Japan.
[4] Faculty of Engineering, Thammasat University, Thailand.

*Corresponding author's e-mail: klaileejira@gmail.com

Abstract. There is a growing concern in traffic accident rate in recent years. Thailand has an average death rate of 24,326 people per year, the second highest globally. It is now down to 32.7 per 100,000 inhabitants, with 22,491 deaths per year, with an average of 60 deaths per day. While Thailand has the third-highest proportion of motorcycle-related deaths globally at 74.4%, it has a population of over 66 million, with a fatality rate of 24.3 motorcyclists per 100,000 people. In addition, when considering the report of the leading presumptive causes of road accidents, it was found that the causes of the crash can be classified as follows: general characteristics of collisions, causes of collisions (human factors, vehicle factors and road and environment factors). This paper focuses on the case of suburban area and applied the spatial-statistical analysis to identify the risk locations of accidents (known as "hot spots"). Kernel density estimation, temporal data plots and space–time pattern mining tools are used to describe spatio-temporal hotspots. The finding can help in motorcycle traffic accidents reduction and effectively improve road safety situation which is crucial to investigate the root cause of traffic accidents with an in-depth understanding of spatial patterns of this problematic.

1. Introduction

Road traffic accidents have become a leading cause of death among young people aged (15–29) years old and are projected to be the 7th leading cause of death for all age groups globally by the year 2030 with highest mortality rates concentrated disproportionately in low and middle-income countries [1]. The mortality rate increased in 27 low-income countries and 60 in middle-income countries, more than the 17 percent increase in the high-income death rate [1], [2]. However, about half of all deaths are in the small, 2-3-wheeled vehicle group and pedestrians, especially traveling by motorcycle. Thailand is a highly populated, low-income country where traffic accidents and related mortality are significant concerns [1], [3], [4]. Thailand found the third highest number of motorcyclists fatalities globally after the small nations, which accounted for 80 percent of motorcycling fatalities but only 17,379 in population and the Maldives. The proportion of deaths caused by motorcycles is 75%, however the number of populations is only 427,756. While Thailand has the third highest proportion of motorcycle-related deaths globally at 74.4%, it has a population of over 66 million, with a fatality rate of 24.3 motorcyclists per 100,000 people [1], [4], [5]. Under this circumstance, the transport regulator and traffic law enforcers are more concerned than earlier to ensure the road safety [6] under the availability of the Motor Vehicle Act 1979, the Road Transport Act 1979, the Road Traffic Act 1979 and the

Highway Act 1992 [7], [8], [9], [10], including regulations on traffic management and road safety. However, the objectives of each law enforcement agency vary according to the specific task of each agency as well as not reflecting in the form of actual enforcement and more emphasis on cars and larger vehicles rather than pedestrians and motorcycles. Especially motorcycles, it is considered more vulnerable to road accident than any other vehicle types which is also found more than 20 million registered motorcycles in the country [11]. From the factual problems that arise, it is found that the enforcement of road safety laws in Thailand still does not give level of importance to traveling by motorcycles, such as setting the speed on the road at the same rate for all types of vehicles, traveling together on the same road and the use of traffic lanes for a variety of vehicles [4], [5]. This paper focuses on the case study of Pathumthani Province as a suburban area of Bangkok (Capital city of Thailand) and applied the spatial-statistical analysis to investigate the risk areas of motorcycle accidents (known as "hot spots") in geographic space [12], [13]. Kernel density estimation, temporal data plots and space–time pattern mining tools are used to describe spatio-temporal hotspots [14], [15]. It reduces traffic accidents and improves road safety which is crucial to understand traffic accidents. An improved understanding of spatial patterns of traffic accidents can make accident reduction efforts more effective for the vulnerable group of motorcyclists. Some other important factors may impact the distribution of traffic accidents, including natural and environmental characteristics, e.g., physical environment (steep slope, sharp turn), the configuration of highway networks (locations of access and egress points, deficient design and maintenance of highways, etc). All of these factors more or less are associated with distinct spatial patterns as well [12], [14], [15].

2. Material and Methodology

2.1. Suburban context and accident dataset

This study conducted on identification of suburban motorcycle traffic accident hotspots using gis-based spatial analysis in Suburban Area, Pathumthani province by using Kernel density estimation (KDE) approach. Pathumthani Province is distant from Bangkok (the capital of Thailand) to the north with the ratio of the city area to total area greater than 42.30 percent. The immigration rate is at +2.24, which is the highest rate in the metropolitan area around Bangkok Metropolitan Region [16]. Currently, Pathumthani Province has a rapid expansion of urban areas which lead to traffic congestion. It has been a main problem in the suburban areas of Bangkok that can be considered from the ratio of travel volume to road capacity (Vehicle Ratio (VCR)) during the morning rush hour of value greater than 1.00 [16], [17]. Furthermore, it is noticeable that road safety issues with the death rate from road accidents per 100,000 population in Pathumthani equal to 9.628, ranked no. 1 in the metropolitan area [18]. Therefore, in this study, data on motorcycle accident in Pathum Thani province from 2011 to 2020 was found the rate of fatalities tended to increase significantly during 2017 [19]. However, the proportion of motorcycle accidents accounts for more than 90% (figure 1). In addition, considering the age and number of accidents, it was found that the age range of 10-30 years was the group with the most accidents. Considering the gender, it was deceased in the same age group which was found males motorcyclists had more risk than three times of the fatality rate than females (figure 2 and figure 3).

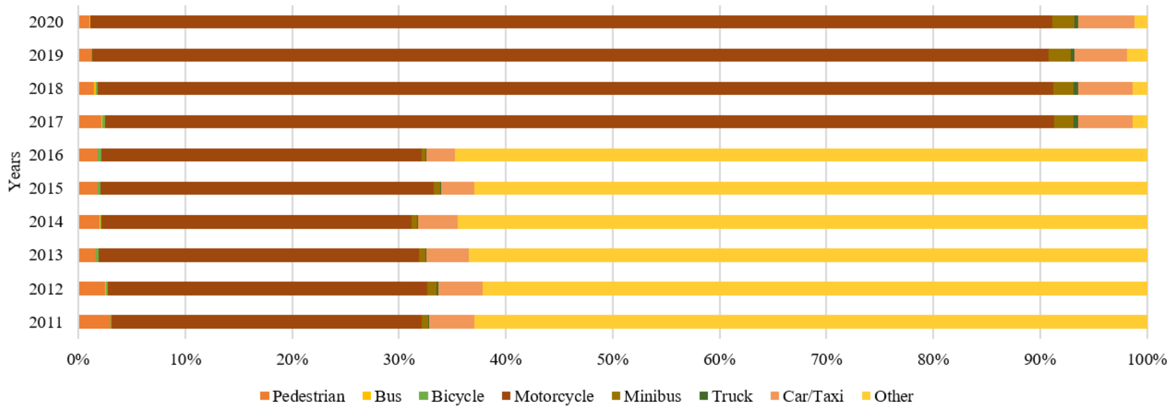

Figure 1. The proportion of accidents in each type of vehicle

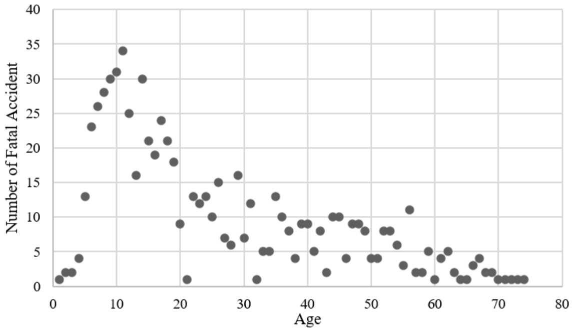

Figure 2. Relationship between of age range and number of fatal accidents

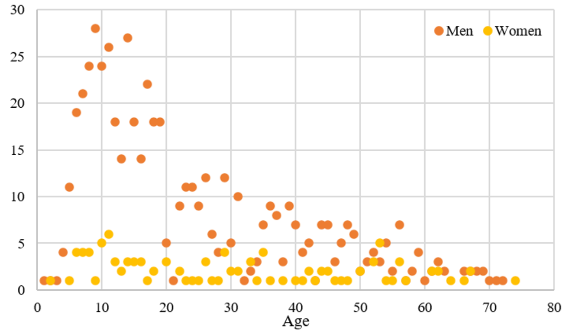

Figure 3. Relationship between age and gender of fatal accident

2.2. Kernel density estimation (KDE)

Previous studies demonstrated that conventional kernel density estimation (KDE) has been employed in several safety studies in order to detect the crash hazard regions [14],[15]. The function presents a set of points as entrance and creates a density level. At first, the density level of each independent and distinct point is defined with the highest amounts, which are recognized by using their location from the zero point. The density level for a point out of a specified radius equals to zero. Each of these separated density levels will be added to others in order to create continuous density levels across the study area [6], [20].

$$f\,(x,y) = \frac{1}{nh^2}\sum_{i=1} K\left(\frac{d_i}{h}\right) \tag{1}$$

where $f(x, y)$: density estimate at the location (x, y), n: number of observations, h: bandwidth or kernel size, K: kernel function and di: distance between the location (x, y) and the location of the i^{th} observation. The prior methods characterize patterns for raw count data that do not account for spatial variation in the population at risk (figure 4). After that, putting the kernel boundary leads to a continuous and smooth level creation that all spaces introduce a level of density analysis. A circular neighbourhood around each feature point (the accident) can be analysed and then a mathematical equation is applied that represents from 1 at the position of the feature point to 0 at the neighbourhood boundary.

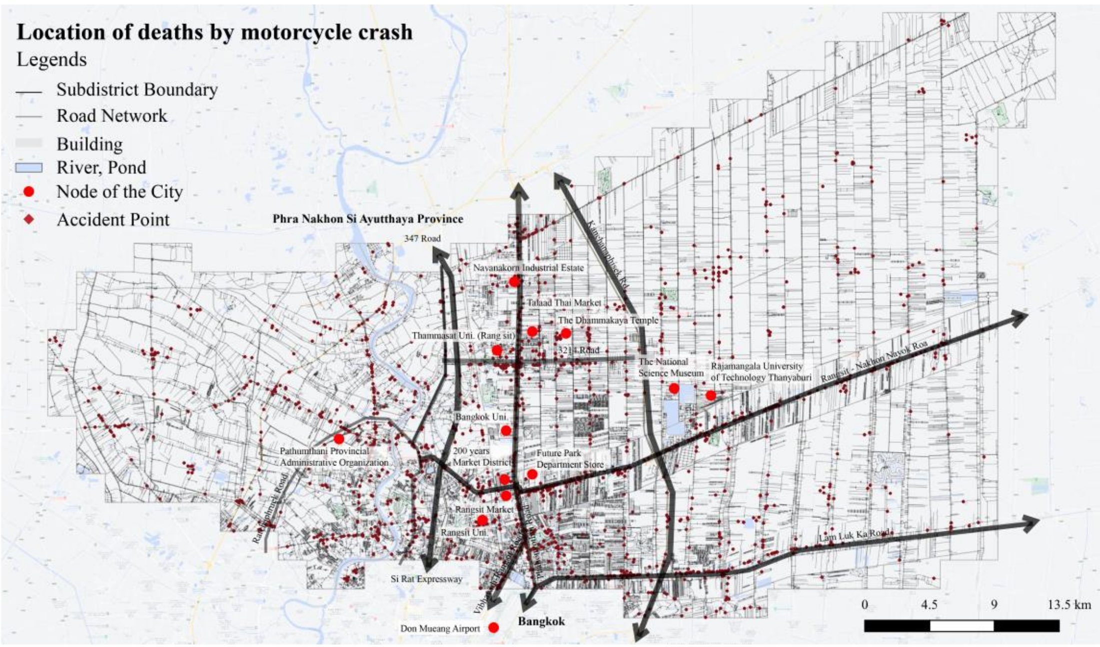

Figure 4. Location of deaths by motorcycle crash

3. Result of Analysis and Conclusions

The analysis results revealed that the hotspot areas are located in intersections on main roads which is consistent with other studies [21], [22]. The finding demonstrated that there are many conflict areas, including the surrounding area among various activities, e.g., academic areas, commercial areas, and crowded residential areas [23], [24], [25]. The identification of hotspots will be considered as a solution based on the risk location and its characteristic of built environment as shown in figure 5.

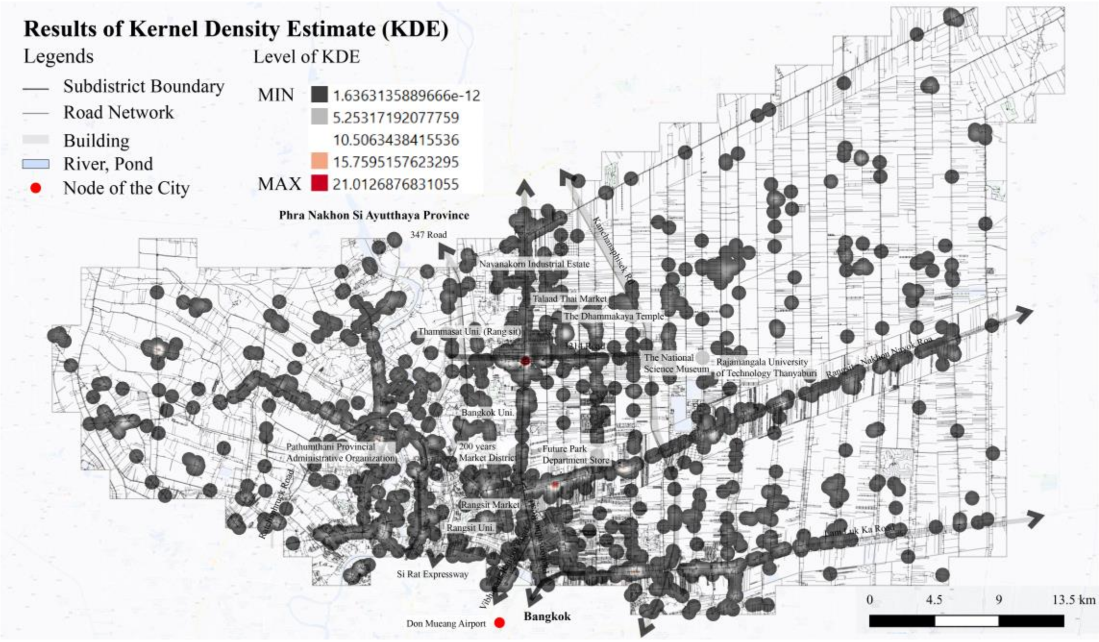

Figure 5. Results of Kernel Density Estimate (KDE)

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Authors' background

Your Name	Title*	Research Field	Personal website
Jirawan Klaylee	Ph.D candidate	Smart Transportation Planning and Smart City	https://www.researchgate.net/profile/Jirawan-Klaylee
Pawinee Iamtrakul	Assoc.Prof.	Transportation Planning Urban Planning Infrastructure Planning	https://www.researchgate.net/profile/Pawinee-Iamtrakul
Virach Sornlertlamvanich	Dr.	Artificial Intelligence, Machine Learning, Knowledge Representation	https://www.virach.com/