Analysis of Accident Sites from Motorcycles among High School Students Using Geographic Information Systems, Sukhothai Province

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Abstract
Road accidents are a major global problem, especially accidents from riding a motorcycle, as these affect both human life and property. Therefore, identifying accident sites is important for accident prevention. This study aimed to analyze the density of accident sites involving motorcycles among high school students in 2019 by using Geographic Information System data (GIS) in Sukhothai Province. In the study, in-depth interviews were used with respondents, including high school students who had accidents on motorcycles, and traffic police officers who were responsible for investigating accidents in schools. In addition, reports of accident sites were used to arrange GIS data layers and analyze the density of the accident sites using Kernel Density Estimation (KDE). The study results revealed that accidents occurred at 217 accident sites in the study area. The map of accident sites and density was created by using GIS data. The areas with accidents in heavy traffic were the roads in the three main districts: Mueang, Si Samrong, and Sawankhalok. Regarding the analysis, accidents were caused by fast cut-off riding, narrow road shoulders, and road users' non-compliance with traffic regulations. The study results were submitted to traffic authorities, schools, departments responsible for rural roads, and local government organizations, and used for planning and developing models to prevent traffic accidents involving motorcycles among high school students through the student council.

Keywords: Accident Sites, Geographical Information System, High School, Kernel Density Estimation, Motorcycles

1. Background and Statement of Problems

The average death rate from road accidents worldwide is 155 cases/hour or 3,700 cases/day, whereas the injury rate is 136,987 cases/day and 3/4 of these are males. It is also found that the injury and death rates are increasing in developing countries, and more than half of the death cases involved motorcyclists (23%), pedestrians (22%), and cyclists (4%) [1]. According to the 2020 estimation of the Road Safety Center in Thailand, Thai people died from traffic accidents at an average rate of 2.5 cases/hour, 60 cases/day, or 22,281 cases/year while the injuries arose at an average rate of 107,542 cases/year. Such rates were ranked highest among ASEAN countries and in 9th position in the world, with the death rate of 36.2 cases/100,000 population [2]. Based on the death certificates, traffic accidents are the leading cause of death among children aged 10 – 14 years [3]. In 2019, the death rate of Thai youths from crashes on the roads was 42.6 cases/100,000 population, considered as the highest rate in the world. The group with the highest number of deaths was aged 15 – 18 years; i.e., the high school age. Every day, 13 teenagers died on average, while 800 were injured, 50 severely, and 7 became disabled. Accordingly, 4/5 of the deaths were males [4]. Such losses were ranked second in terms of years of life lost due to death or disability. World Health Organization [5] According to the investigation results, motorcycles are the vehicles which are most relevant to accidents at 40 – 70% [6]. Sukhothai is a province with highly ranked statistics of traffic accidents in Health Region 2, and shows an increasing trend. Based on the statistics in 2016 – 2018, the injury rates from traffic accidents were 684.45, 734.2 and 798.31 per 100,000 population, respectively [7].

In the case of high school students, the injury rate was high at 414.34, 459.31, and 487.32 per 100,000 population, respectively, whereas the death rate was 5.6, 8.3, and 10.5 per 100,000 population, respectively. The vehicles most commonly involved in traffic accidents were motorcycles (81.3) during the accident period of 3 pm – 11 pm [8]. Traffic accidents involving motorcycles were mostly found in school aged riders which is an important age for the national future. Therefore, the researchers were interested to study factors affecting traffic accidents involving motorcycles among high school students in Sukhothai Province in order to create models for preventing death and injury from road accidents.

Geographic Information System (GIS) is an instrument and a database used for recording, editing, improving, analyzing, displaying, and reporting spatial data through a computer. GIS is also a connector of relationships among various data so it is used for managing, planning, and solving different problems. GIS is considered as technology distinctive in analyzing and presenting spatial data, especially in the form of maps, so it is widely applied. In this study, GIS was used to create a database for analyzing accident sites. GIS has popularly been used in many studies since it is a high-performance computer system for storing, editing, and analyzing spatial data. Moreover, GIS outcomes are reliable since the system is controlled by data, conditions, and criteria. The GIS analysis can be used to develop a database of traffic accidents and dangerous/risk sites of traffic accidents, and the severity index (S) is used to classify risk levels of dangerous sites, numbers of traffic accidents, numbers of dead, numbers of seriously injured, numbers of injured, and roads and surrounding factors which include road types, road surfaces, lane widths, lighting, and land use. It is considered that the examples of analyzing dangerous sites with GIS can lead to guidelines for preventing and reducing traffic accidents in the area.

This research arranged a GIS database to support the management of traffic accidents involving motorcycles among high school students in 9 districts of Sukhothai Province in the areas where the traffic was the heaviest in Sukhothai in order to analyze the density of traffic accidents for risk assessment in those areas. The study results can lead to identification of the risk points, and then to warn, provide surveillance, manage solutions, and carry out risk reduction at those risk points.

2. Research Question and Objectives

This study is focused to determine how a GIS base system can be used for recording, correcting, improving, analyzing, displaying, and reporting accident data in Sukhothai Province. The Objectives of the study are 1.) To create a GIS database of accident sites involving motorcycles among high school students in Sukhothai Province, and 2.) to analyze the density of traffic accidents involving motorcycles among high school students by using the Geographic Information System in Sukhothai Province

3. Methods

This qualitative research was implemented to study geographical situations with effects on traffic accidents involving motorcycles among high school students. This study was a part of an advanced mixed-methods research design with multistage evaluation design in the project of Model for Preventing Traffic Accidents Among High School Students Through the Student Council in Sukhothai Province. The study was approved in terms of its research ethics by the Human Research Ethics Committee, Naresuan University, with the project code IRB No. P2-0158/2565 and the research project approval COA No. 307/2022.

3.1 Population and Samples

- The respondents were divided into 2 groups selected with criterion sampling as follows. Group 1 Motorcyclists who were high school students in Sukhothai Province, had a history of having motorcycle accidents in 2019, and lived in Sukhothai Province. The number of these motorcyclists was 16, or until the data were saturated.

- And group 2 Traffic police officers who worked in Sukhothai Province, and were responsible for managing and reporting traffic accidents. The number of these traffic police officers was 9, or until the data were saturated. The in-depth interview was applied to acquire the in-depth data, which reveals the traffic accident situation, so the preventive plan can be set inclusively.

3.2 Research Instruments

In-depth interviews and the following instruments (**Table 1**).

Table 1: Research instrument for rolls and duties

No.	Types of Instruments	Roles/Duties
1.	Data layer of the study area boundaries, i.e., a GIS spatial data layer in shape files with the scale of 1: 50,000, developed by the Royal Thai Survey Department, Ministry of Defense	Use for determining physical geographical scale.
2.	Data layer of transportation routes, developed by the Department of Public Works and Town & Country Planning, Ministry of Interior	Use for identifying administrative districts.
3.	Data of traffic accidents in 2019, from Traffic Works, Sukhothai Provincial Police Station [9].	Use for managing lawsuits.
4.	Data of traffic accidents in 2019, from Non-communicable Disease Affairs, Sukhothai Provincial Health Office [10].	Use for supervising and preventing accidents.
5.	Survey about traffic accidents: Camera Tools and Equipment Used in the Study	Use for taking photos at accident sites
6.	Computer set and operating system	Use for recording data.
7.	Spreadsheet program	Use for processing data.

3.3 Research Procedure

1. Collect the data of traffic accidents in 2019 from Non-communicable Disease Affairs, Sukhothai Provincial Health Office. The data were in the form of an IS on line files which included main data such as accident sites (IS online is the data system/injury monitoring report to use with the program. IS Online can connect with the online database of hospitals across Thailand), photos of accidents, vehicle types in accidents, and number of injured and dead people. The data were from all hospitals in the 2019. [10], and were screened to select only the cases of accidents involving motorcycles, encoded ICD 10 V20 – V29, occurring with high school students at the age of 15 – 18 years who were selected for the in-depth interviews.

2. Download the KML files through the website of Traffic Works, Sukhothai Provincial Police Station, which was responsible for supervising and managing all traffic works in Sukhothai Province. The files included main data such as accident sites, photos of accidents, vehicle types in accidents, and the number of injured and dead people.

3. Arrange the data into the MIS (management information system) files by using the spreadsheet program.

4. Perform the fieldwork survey at the actual sites of traffic accidents. Record the data in a survey record. The purpose was to survey additional aspects of traffic accidents. Then, take photos and collect the data of location coordinates through the GPS device.

5. Put the coordinate data (East: X, and North: Y) collected from the survey in association with the data of each site in the spreadsheet program, as shown in **Figure 1**.

6. Import the survey data and coordinate values through the GIS program. Create the GIS data layer of the accident sites in point shape files and the GIS data dictionary.

7. Import basic data including area boundaries, main roads, and secondary roads. Then, create maps of accident sites.

8. Estimate the spatial density of the accident sites by using Kernel Density Estimation (KDE) to analyze the areas from the center and Network Kernel Density Estimation (NKDE) to analyze the area networks.

9. Classify the density of traffic accidents into 3 levels: high, moderate, and low. Create maps of traffic accident density in the areas.

10. Record, synthesize, and conclude the study results.

In the analysis, the step of *accident information from motorcycle in Sukhothai* was performed by collecting, screening, and selecting only data of motorcycle accidents. The data were encoded ICD 10 V20 – V29. The in-depth interview and the on-site survey were performed in the actual accident sites. In the step of *modify GIS layer*, the survey data and coordinate values were imported to create the internal dot-shape files and data dictionary

through the GIS program. The *spatial analysis* was performed by surveying and taking photos in the actual accident sites whereas the *behavioral analysis* was conducted with the in-depth interview in all cases. The spatial density of accidents was assessed at the accident sites by using Kernel Density Estimation (KDE) to classify density of road accidents. The step of *reflect back information* was implemented by returning data to Road Safety Center, Traffic Police offices, and Sukhothai Basic Education Office.

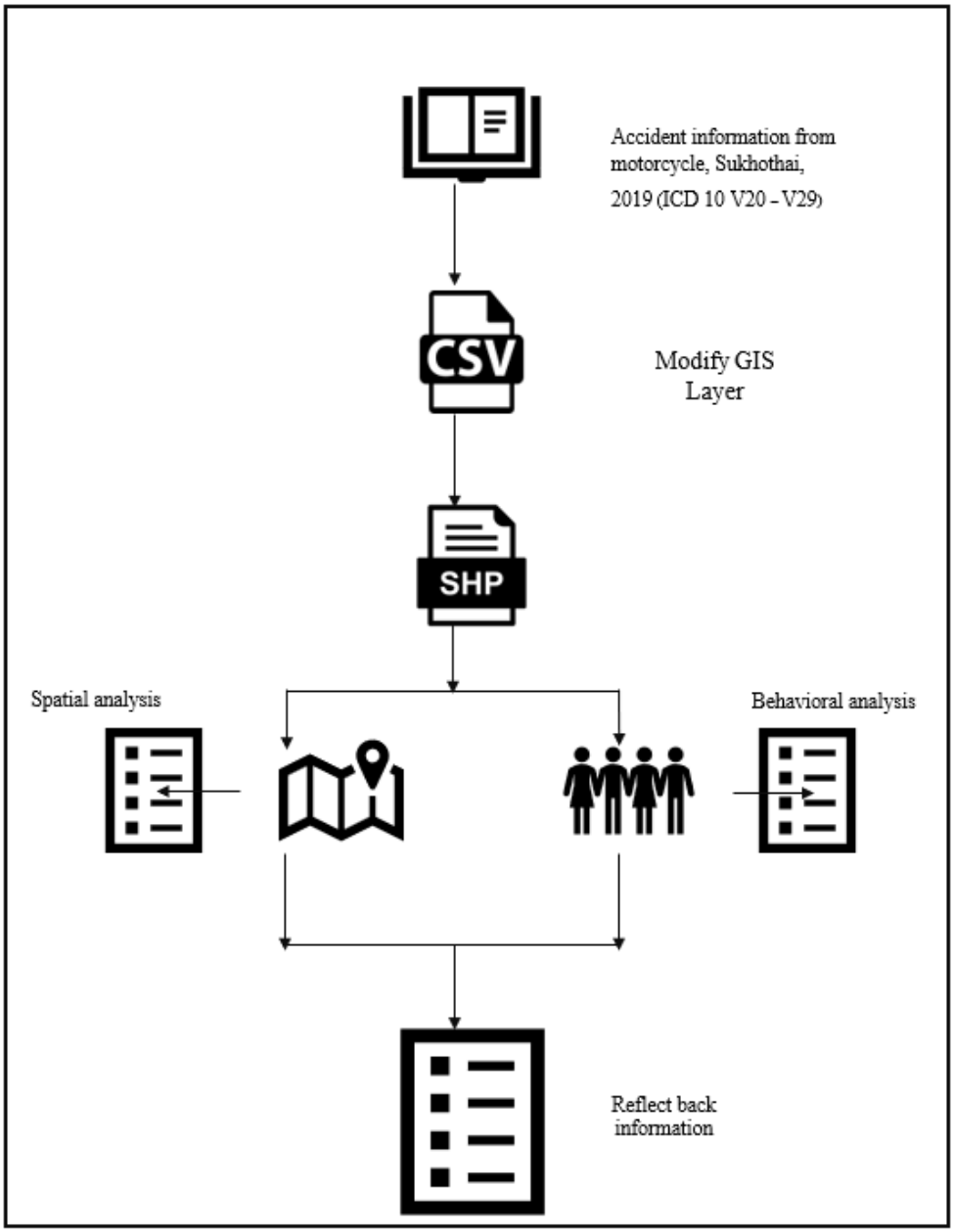

Figure 1: Flow chart

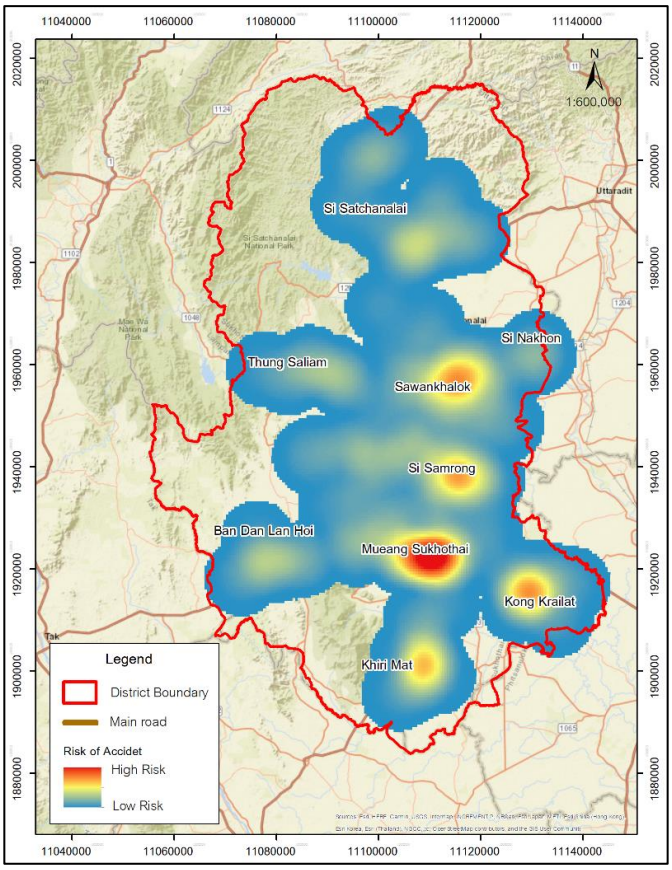

Figure 2: Sukhothai province, Thailand

4. Research Results

Sukhothai Province is located in the lower north and upper central region of the country (**Figure 2**). There is a main road which connects Phitsanulok Province, which is an Indochinese intersection, to Tak Province. Travel to Sukhothai is convenient via various modes. The Yom River flows through the city center. Sukhothai covers an area of 4,112,577 rai or 6,596.092 square kilometers in connection with the nearby provinces as follows:

North: Connect to Wang Chin District and Sung Men District in Phrae Province; and Laplae District in Uttaradit Province.

South: Connect to Phran Kratai District in Kamphaeng Phet Province and Bang Rakam District in Phitsanulok Province.

East: Connect to Phrom Phiram District in Phitsanulok Province, and Phichai District in Uttaradit Province.

West: Connect to Mueang Tak District in Tak Province, and Thoen District in Lampang Province.

Regarding the accident sites, there were 217 accident sites involving motorcycles and high school students in the 2019 fiscal year in the areas of Sukhothai Province. The GIS data layer of the accident sites was created with attribute data of dates, months, time, party 1, party 2, party 3, accident aspects, route aspects, accident positions, roads, injuries, deaths, and location coordinates of traffic accidents. This means the data about accidents, the number of accident sites involving motorcycles and high school students in the 2019 fiscal year in the areas of Sukhothai Province, which were analyzed by GIS in combination with KDE and NKDEX by using the KDE and NKDE methods, a map of traffic accident density was created to display the distribution of traffic accidents in 9 districts, as shown in **Figure 3.** In the site analysis of traffic accidents by using the GIS with KDE and NKDE, the density map displayed the traffic accident density in three districts: 1) Mueang, 2) Si Samrong, and 3) Sawankhalok. The description of each district is presented below.

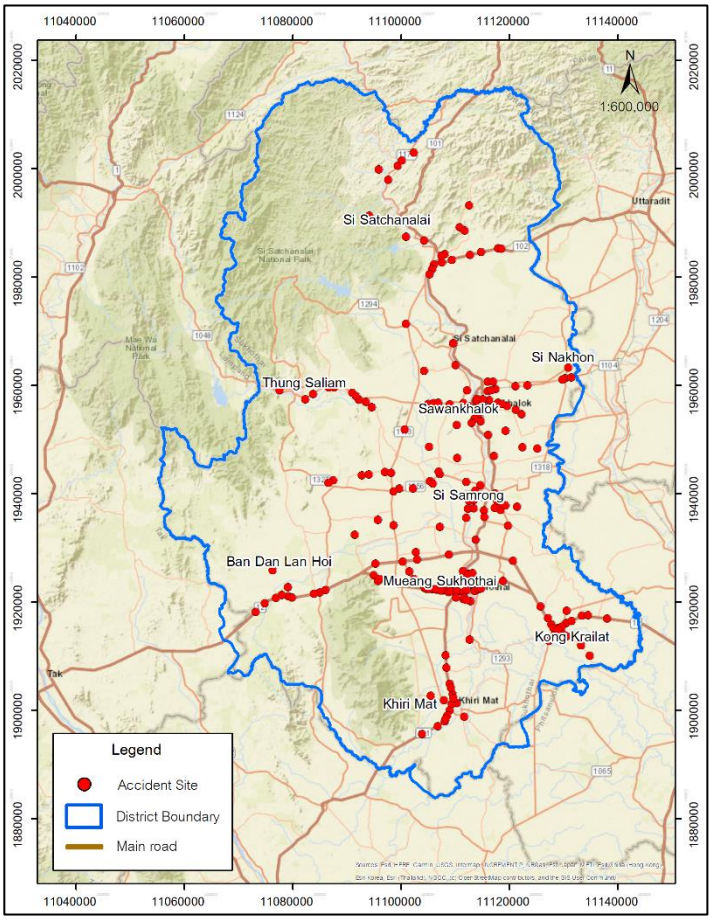

Figure 3: The overview of accident sites involving motorcycles among high school students in 9 districts of Sukhothai Province in 2019

4.1 Mueang District

The areas with a high density of traffic accidents were Khong In-Si Intersection, the intersection in front of Sukhothai Wittayakom School, and Tri Rat Intersection, as shown in **Figure 4.**

4.1.1 Khong In-Si Intersection is an intersection in the city center with traffic jams in the morning and evening on both the inbound and outbound routes as the main routes to Udomdarunee School, a park, exercise yard, food market, and product markets, etc. In addition, there are many workplaces in this area. Due to the lack of accident-warning signs and traffic light, motorcycle crashes frequently occurred at the intersection area. The main causes of accidents were rear-ending collisions, pushing into a lane, and not giving way to others.

4. 1. 2 The intersection at the front of Sukhothai Wittayakom School includes main roads for commuters as it is near the school and a technical college. It has the route to Big C Supercenter and another main route to Tak Province. Therefore, accidents often occurred in the morning and evening rush hours.

4.1.3 Tri Rat Intersection is another risk point as it is a T-junction to night food markets, the city center, and provincial hall. People usually commute to buy things at the market, go to work, and eat at the restaurants near this intersection. Therefore, motorcycle accidents frequently occurred in this area. The main causes of accidents were overtaking in the congested area and cutting-off other road users. These accident sites are displayed with colors as shown in **Figure 5**, while red to indicate repeated accidents in the past 3 years, and yellow to indicate repeated accidents in the past 5 years.

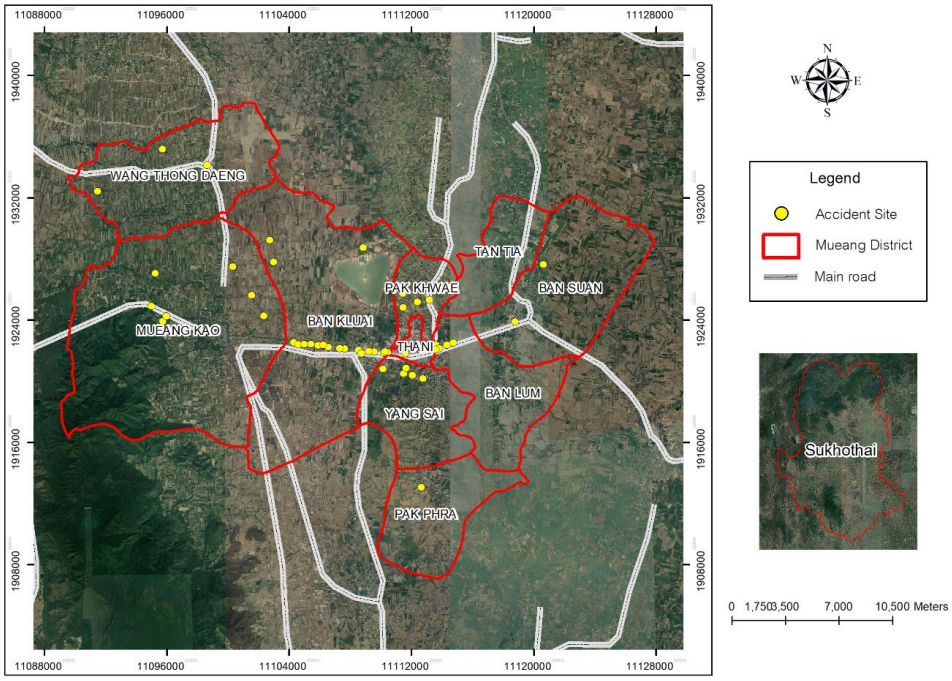

Figure 4: Density of traffic accidents involving motorcycles and high school students in Mueang District, Sukhothai Province in 2019

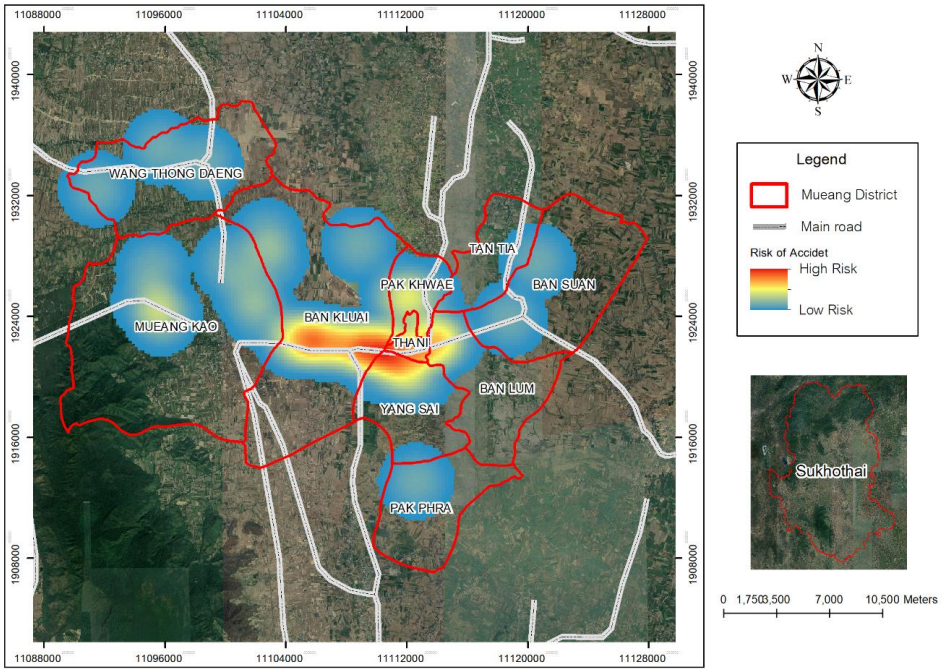

Figure 5: Repeated accident of traffic accidents involving motorcycles and high school students in Mueang District, Sukhothai Province in 2019

4.2 Si Samrong District

The areas with a high density of traffic accidents were the intersection with traffic light at the back area, Wat Photharam Intersection, and the shortcut route to Wang Luk Sub-district in connection between Si Samrong and Mueang Sukhothai, as shown in **Figure 6.**

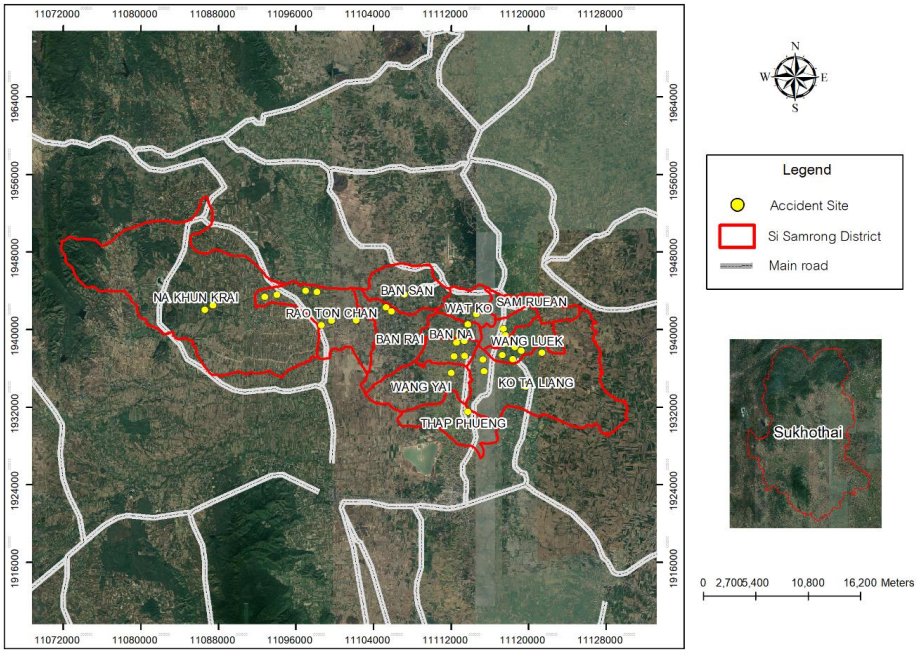

Figure 6: Density of traffic accidents involving motorcycles and high school students in Si Samrong District, Sukhothai Province in 2019

4.2.1 The intersection with traffic lights at the back area is a 2-lane bypass from the main road connecting Mueang District and Sawankhalok District. Vehicles frequently running on this road were agricultural vehicles and motorcycles. Students were unaware of other vehicles. The causes of accidents were fast riding, the narrow road, and improperly maintained vehicles.

4.2.2 Wat Photharam intersection connects the main road to a community road. From the investigation, it was found that motorcycles ran on the 4-lane main road in connection to the 2-lane road. The causes of accidents were fast riding, rear-end collisions, and insufficient lighting.

4.2.3 The shortcut route to Wang Luk Sub-district connecting Si Samrong and Mueang Sukhothai is another route which high school students used after school. This route connects to Phitsanulok Province. The causes of accidents were fast riding, sudden turning, and a curved route without clear warning signs. These accident sites are displayed with colors as shown in **Figure 7**, while red to indicate repeated accidents in the past 3 years, and yellow to indicate repeated accidents in the past 5 years.

4.3 Sawankhalok District

The areas with a high density of traffic accidents were Saphan Chan Intersection, Chanthararophat Intersection, and Kai Yang Phikunthong Intersection. According to the statistical analysis, it was found that there were averagely 3 accidents/ year at Saphan Chan Intersection, 2 accidents/ year at Chanthararophat Intersection, and 3 accidents/ year at Kai Yang Phikunthong Intersection as shown in **Figure 8.**

4.3.1 Saphan Chan intersection includes 2-lane roads in connection to Si Satchanalai District. In the morning and evening, it is crowded with agricultural and student vehicles. The causes of accidents were fast riding, damaged traffic signs, and narrow road shoulders. There were 3 accidents/year.

4.3.2 Chanthararopat intersection includes 4-lane roads with fast commuters as there are community areas and a flea market. The traffic was heavy from afternoon to evening. The causes of accidents were shoving sideways, cutting-off other vehicles, and sudden turning. There were 2 accidents/year.

4.3.3 Kai Yang Phikunthong intersection is a shortcut to the back road. There is a petrol station and some convenience stores. The causes of accidents were fast riding, cutting-off other vehicles, sudden overtaking, and unclear warning signs. There were 2 accidents/year. These accident sites are displayed with colors as shown in **Figure 9**, while red to indicate repeated accidents in the past 3 years and yellow to indicate repeated accidents in the past 5 years.

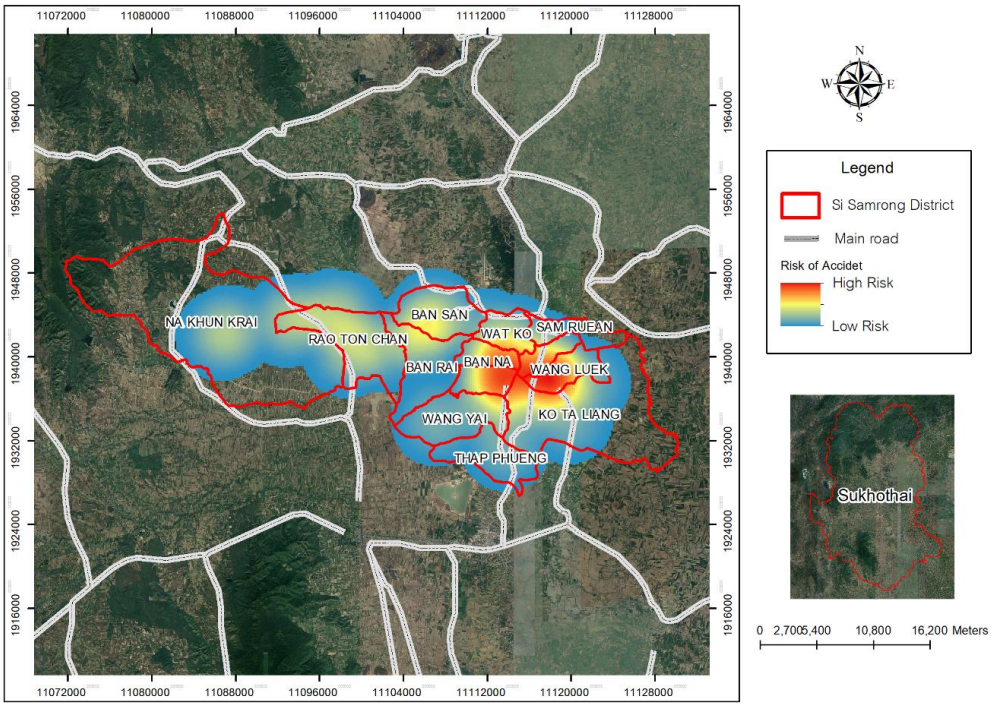

Figure 7: Repeated accident of traffic accidents involving motorcycles and high school students in Si Samrong District, Sukhothai Province in 2019

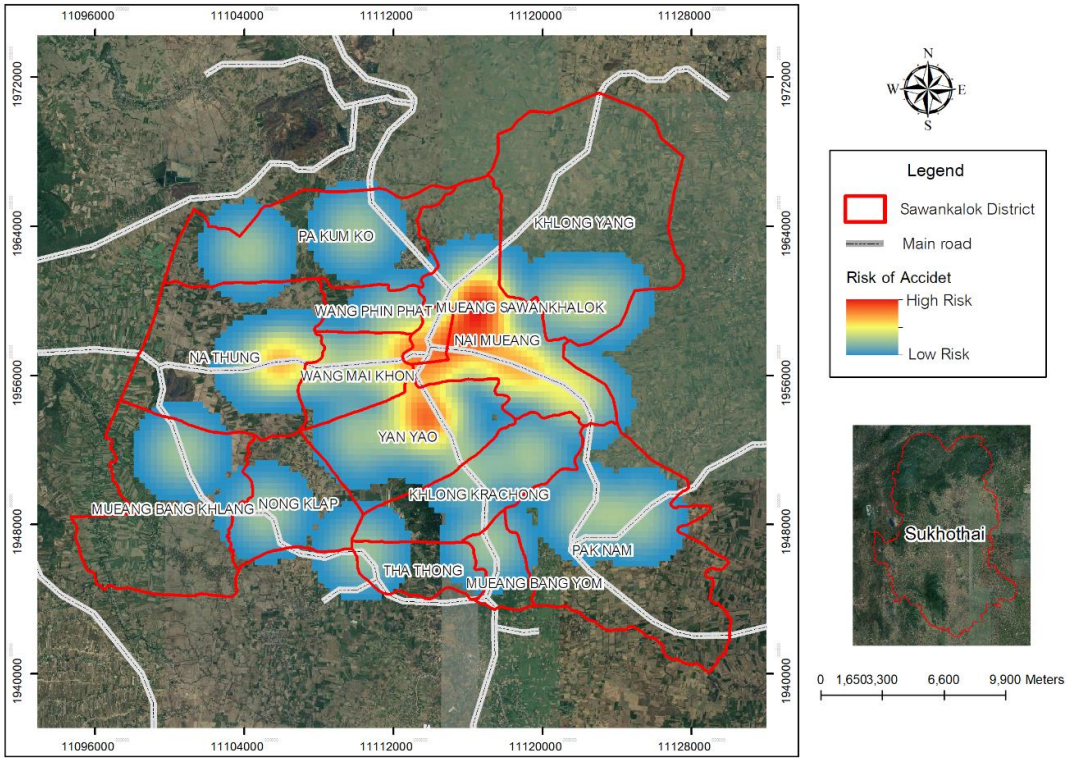

Figure 8: Density of traffic accidents involving motorcycles and high school students in Sawankhalok District, Sukhothai Province in 2019

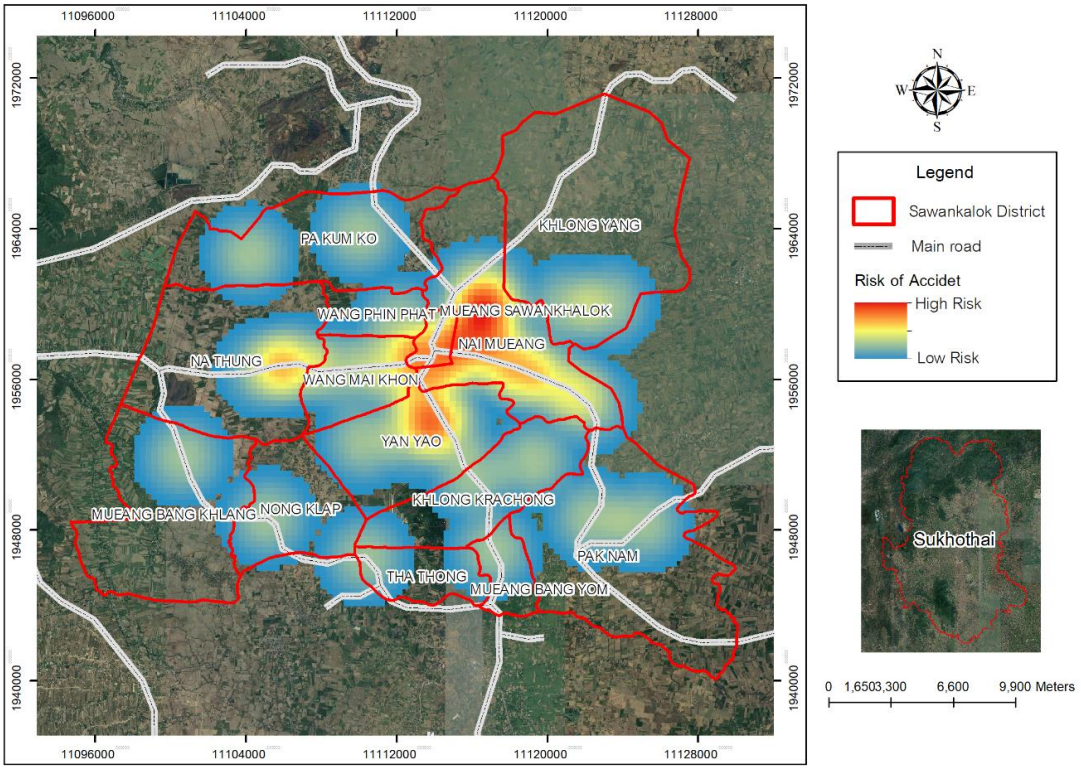

Figure 9: Repeated accident of traffic accidents involving motorcycles and high school students in Sawankhalok District, Sukhothai Province in 2019

5. Conclusion

The Geographic Information System (GIS) is suitable for collecting the data of traffic accidents and other relevant data for planning to reduce the risks of traffic accidents in the future. Such feedback provides empirical evidence which is useful in utilizing communication technology to raise awareness of the need to monitor risk points to prevent damage from road accidents. The new findings in this study were: 1) the application of communication technology makes the data reliable to create empirical evidence which can be conveniently used for the data analysis; 2) planning with authentic data enables a better problem-solving approach, and 3) solving traffic-accident problems requires data and participation from all sectors.

Additional analysis and supporting details are as follows:

1. The geographic information system (GIS) is useful because it can provide clear pictures at the accident sites. These pictures can raise people's awareness of caution at the accident sites and dangerous roads in order to plan preventive measures.

2. GIS information can be used for planning accident prevention at the regular points. According to the data collected for 1 year, there was no repetitive accidents.

3. The GIS can create participation of all sectors. At every meeting arranged by road safety centers, relevant agencies discuss about relevant issues for collaboratively plan preventive measures with evidence of the meeting minutes and monthly monitor of progress

One discovered knowledge is to have the perspective on the clearer problem-solving. The in-depth interview during the site visit makes it clear that the clear specification of the site helps to prevent the reoccurrence of road accident and set the preventive measure for the nearby risky locations to minimize the road accident.

Discussion: To solve road accident problems requires collaboration from all sectors and power of data which must be true, accurate, valid, and verifiable. The GIS system can support such issues.

Findings and Discussion

According to the analysis of traffic accidents and the additional fieldwork survey, it can be concluded that most accidents in the Sukhothai area occurred at intersections or junctions [10], and on main roads. The intersections or junctions included Khong In-Si Intersection, Saphan Chan Intersection, Tri Rat Intersection, and the intersection at the night food market. The causes of accidents at these sites were analyzed and it was found that the causes were careless, fast riding, immediate cutting-off other road users, narrow road shoulders, and non-compliance to traffic regulations. The study of Hisam et al., [11] found that accidents in Malaysia often occurred in the afternoon at intersections.

The accident sites on the main roads were Highway 12 connecting Phitsanulok, Sukhothai, and Tak Provinces while other accident sites were the secondary roads to Sawankhalok, Uttaradit, and Mueang Sukhothai. The main causes of motorcycle accidents among high school students in the areas were overtaking, cutting-off other vehicles, careless riding, violation of traffic lights, and non-compliance with traffic regulations. The supporting factors of accidents were engineering design in designing roads, road conditions, the number of lanes, intersections with crossing traffic flows such as intersections near bridge entrances and exits, or large intersections etc. Surroundings are another important factor, especially in the lack of traffic signs, rough road surfaces, and poor visibility. Moreover, some external controllable factors were the construction of buildings or roads. The causes of traffic accidents in the urban areas were from daily riding behaviors, analyzed from the in-depth interview and hospital history inquiry. The causes of accidents were found 73% from fast riding, 27% from alcohol drinking, and 91% from not wearing a safety helmet. Traffic density [12] was different from the rural areas where the main causes of accidents were from fast riding and drunk riding.

The findings of this study are consistent with the findings in the study of Konkeaw et al., [13] which analyzed the density of traffic accidents by using GIS in Nai Mueang Sub-district, Mueang District, Kamphaeng Phet Province. Another study by Ruthirako et al., [14] applied GIS to identify accident sites in Kho Hong Municipality, Hat Yai District, Songkhla Province, whereas the study of Pimsang [15] analyzed Quantum GIS to find the density of land traffic accidents at Naresuan University and the surrounding areas. Moreover, the study of Wongho [16] used the data to determine spatial factors expected to have effects on accidents by dividing areas into grids and calculating means of variables in order to find the relationships with accidents in Phitsanulok Province by using linear regression analysis for the statistical analysis.

According to the analysis, it was found that traffic congestion was the probable cause of accidents occurring during the rush hours from 7 am – 9 am and 3.30 pm – 6.00 pm as these were the travel periods when students went to/from school and people went to/from work. To solve this problem, traffic police officers are required to regulate traffic at different intersections and risk points.

Benefits of the Study

The study results are useful for planning to reduce road accidents involving motorcycles by improving possible risk points. The results can also be used as empirical data for running campaigns to reduce traffic accidents such as by setting community checkpoints, fixing warning signs, and building participation to prevent traffic accidents in order to reduce the loss of high school students who are the nation's future.

Suggestions

Suggestions for applying the study results

1. Relevant agencies can use the study results to manage traffic accidents in their own areas. These agencies include provincial police stations, provincial education authorities, teachers and schools, Sukhothai Highways, Office of Disaster Prevention and Mitigation Sukhothai Municipality, and road safety centres at the provincial and district levels. These agencies can apply the study results to support spatial management of traffic accidents and risk reduction of traffic accidents.

2. Relevant agencies such as local government administrations can use the map of traffic accident density for sharing knowledge with communities to reduce traffic accidents and support safe riding/driving in those areas.

Suggestions for Future Research

1. Spatial data of traffic accidents should be collected continuously for analysis to find causes, provide warning, conduct surveillance, and prevent traffic accidents, and to reduce risk effectively.

2. Traffic accidents outside the urban areas should be studied to identify risk points and to compare risk aspects, leading to effective management of urban and non-urban traffic accidents.

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