Mapping of Traffic Accidents in Labuhanbatu Regency using GIS Support

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Abstract. Labuhanbatu Regency is a regency located in the North Sumatra province of Indonesia. This regency is crossed by a national road across Sumatra that connects provinces on the island of Sumatra. This has led to an increase in traffic accidents in this region. The number of accidents reached 114 accidents in the official police report for 2018. This study discusses locations that have a high frequency of accidents and represents them in the form of spatial data. The data used is based on the official report of the accident from Labuhanbatu Resort Police in 2018 which consists of 3 attributes namely, accident id, time of the accident, and location of the accident. The method used is to create a density map to calculate complexity in certain areas using Quantum GIS. This study uses the Kernel Density Estimation (KDE) method with a search bandwidth in an area of 300 meters. The results of the study are accident heat maps for the study area and related to the inputted attributes. The highest heatmap in the Bilah Hilir and Panai Tengah sub-districts with 25 attributes and 24 accidents included. The use of heatmap can produce spatial data that is easier to understand because it's clustering from the same area. In this study, clustering is done based on the time of occurrence to obtain a heat map in red to black for the density level based on the frequency of accidents.

1. Introduction

Labuhanbatu Regency is a regency in the province of North Sumatra Indonesia and has an area of 2,561.38 km\(^2\) with a population of 478,593 people\textsuperscript{[1]}. Bordered by Labuhanbatu Selatan and Labuhanbatu Utara Regencies, this regency is crossed by a trans-Sumatran national road that connects the provinces on the island of Sumatra, thereby increasing the population in this area. This increase in population indirectly increases the risk of transportation problems\textsuperscript{[2]}. This has led to high rates of traffic accidents in this region\textsuperscript{[3]}. Data in 2018, the number of accidents reached 114 events that resulted in serious injuries and death\textsuperscript{[4]}. This data increased by almost 10\% from the previous year which only occurred 93 accidents\textsuperscript{[1]}, so that it requires effective attention and treatment because it causes harm to the community.

Chances of accidents and their actual effects can be reduced by analyzing the incidents\textsuperscript{[5]}. The results of the analysis will build the right solution by involving road designers, traffic control devices, and more effective traffic police surveillance\textsuperscript{[6]}. However, this solution is not enough because it still requires a spatial analysis of the accident zone. The spatial analysis will extract new information that is different from spatial data\textsuperscript{[7]}. The optimal solution requires an analysis of Spatio-temporal patterns in the area of...
the accident. The formation of this pattern can only be achieved by the application of geospatial technology[6].

This study aims to identify locations that have a high frequency of accidents in a certain period and represent them in the form of spatial data. Spatial databases and their attributes will be developed to classify vulnerable areas[5]. Data will be clustered based on the time of occurrence in the form of a heatmap. Heatmap will explore data clustering so that it can be visually identified as important data entity groups[7]. The attribute used is based on the official accident report from the 2018 Labuhanbatu Police. The results of the analysis will be in the form of spatial heatmap data based on the location of the accident and the number of incidents that occur using the Quantum GIS geospatial application (QGIS). The results of this study are expected to identify areas prone to traffic accidents so that related parties can anticipate and reduce risks that arise in the future.

2. Material and Method
2.1 Study Area
This research was conducted in Labuhanbatu Regency, a district located in the east coast region of northern Sumatra. Geographically, Labuhanbatu Regency is located between 1041’ - 2044’ North Latitude and 99° 3’ - 100° 22’ East Longitude with an altitude of 0 to 700 meters above sea level[1]. The research area is bordered by North Labuhanbatu Regency and South Labuhanbatu Regency. Consisting of 9 sub-districts, the length of roads in this regency reaches 982.78 km with 47.55 km of which are national roads[1].

![Figure 1. Map of the study area](image)

2.2 Data
The research data was taken from moderate and severe accident data that occurred in 2018 based on Labuhanbatu District official police report. In this report, the number of accidents reached 114 events in serious injuries and death occurred in 8 districts. The highest number of accidents occurred in the Bilah Hilir Subdistrict as many as 25 events with the highest frequency occurring in January 18 times throughout 2018.

2.3 Method
Data was collected from January-December 2018. The total number of data reached more than 200 events because it included accident data in the districts bordering Labuhanbatu Regency. But to limit the research, the data processed is only data of events that are in the Labuhanbatu Regency with a total of 114 accidents. Each data contains three attributes, namely the accident id, time, and location of the incident.
After the attribute data is obtained, the data needs to be changed because its value is a specific geographical location in the form of text. The geographical data is re-mapped and made in the form of numerical data that contains the longitude and latitude of the accident location. The mapping of location data is done with the help of Google Maps based on report information. Table 1 shows an example of an accident report from the police whose location is then mapped.

| Id   | Time       | Address                                                                 | Location          |
|------|------------|-------------------------------------------------------------------------|-------------------|
| 001  | 2018/01/10 | Sumatera Highway, HM Said Street, Bilah Barat sub-district, between 294-295 kilometers Medan to Aek Nabara | 2.055068,99.865434 |
| 002  | 2018/01/11 | Sumatera Highway, Janji Village, Bilah Barat sub-district, between 278-279 kilometers Medan to Rantauprapat | 2.143038,99.790310 |
| 003  | 2018/02/14 | Sumatera Highway, Pematang Seleng Village, Bilah Hulu sub-district, between 314-315 kilometers Medan to Kota Pinang | 2.052846,100.025653 |
| 004  | 2018/04/07 | Sumatera Highway, Adam Malik Street, Rantau Utara sub-district, between 285-286 kilometers between Medan to Aek Nabara | 7.2097360,99.817743 |
| 005  | 2018/08/21 | Sumatera Highway, Perbauangan Village, Bilah Hulu sub-district, between 310-311 kilometers between Medan to Kota Pinang | 2.060259,99.986822 |

After the location is obtained, a heatmap will be built using QGIS 3 to get a density map of each input point on the layer. Heatmap will calculate the density of accidents in the required kernel bandwidth. Kernel bandwidth is the distance at the point where the accident area affects the other points[6]. This study uses the Kernel Density Estimation (KDE) method with a search bandwidth in an area of 300 meters. KDE will divide the research area into several pre-determined cells. Figure 2 shows the kernel density analysis method used in the search area along the road. The calculation of kernel density is calculated based on each unit area of the point or feature line using the kernel function to get the right line to each point[8].

![Figure 2. The Principle of Kernel Function[8]](image)

3. Result and Discussion
Based on the official police release, there were 231 accident occurrences throughout 2018 in the Labuhanbatu Regency and other Regencies bordering Labuhanbatu. The regencies include North Labuhanbatu Regency which borders on the north and Labuhanbatu Selatan Regency which borders on the south side. This accident was recorded because it was on the Sumatra causeway connecting the provinces of Sumatra. However, to narrow the research area, accident data was taken for the Labuhanbatu Regency area so that it became 114 events even though the mapping process also included locations outside the Labuhanbatu District area.
Most accident data occurred in the District of Bilah Hilir, respectively in the District of Central Panai, and District of West Bilah. The tabulation of the number of accidents in each district is shown in Figure 3.

![Number of Accidents in each Sub-District](image)

**Figure 3. Number of Accidents in each Sub-District**

As for the frequency of events, most occurred in January, June, and October 2018 with 18, 16 and 14 accidents respectively. The graph of the frequency of accidents every month is shown in Figure 4.

![Number of Accidents in a Month](image)

**Figure 4. Number of Accidents in a Month**

The process of mapping data is done by displaying all the distribution locations of accidents. As can be seen in Figure 4, the administrative map of Labuhanbatu Regency will be displayed as a layer with a database sourced from OpenStreetMap. After the location is inputted, it will be seen the spread of the accident location in the form of a point displacement with a red center and a blue dot with a lot of frequencies occurring in the center point area. In identifying the hotspot where this accident occurred, the majority occurred in the intersection or bend area. This requires attention so that the traffic sign needs to be improved and made arrangements at this point. Several accident sites can be seen in Figure 5.

![Some of the hot spot locations](image)

**Figure 5. Some of the hot spot locations**
After mapping the entire location, the mapping process continued with identifying the frequency of the most populous accidents in the form of a heatmap. The heatmap will result in centralized distribution of accidents and produce hotspots that gather in areas that have a high incidence. Heat mapping is based on the time of the accident. The map change from accident points in Figure 6 to heatmap can be seen in Figure 7. The heatmap in Figure 6 shows the density of each point marked in red. The darker the red, the higher the frequency of accidents that occur in the area. However, this area is not too detailed because the area is quite extensive so that the mapping process is then carried out by taking a sample of several districts in Labuhanbatu Regency.

A more detailed mapping process will be carried out per sub-district, in which the sub-district that will be used as an example is the sub-district with the highest accident rate, Bilah Hilir District. Figure 8 shows the heatmap of the accident location based on accident frequency, whereas Figure 9 heatmap with a larger scale.
A larger-scale heatmap as shown in Figure 9 produces a more detailed image to identify vulnerable areas that have the highest frequency of accidents. GIS support generates a heatmap of areas with the highest density of accidents within a certain period so that it can be used as an analysis for the police and road users.

4. Conclusion
This study produces a heatmap of accident locations in a period that has a high-frequency level in a certain area. The most densely located heatmap is in the Districts of Bilah Hilir and Panai Tengah. The use of heatmaps is more beneficial because it can produce spatial data that is easier to understand because it groups from the same area. In this study, the grouping is done based on the time of occurrence so that a heatmap with red to black is obtained for the density level based on the frequency of occurrence.

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