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Spatial Analysis of Fatal Road Accidents Along the North South Expressway

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Abstract: Road accidents continuously become a major problem in Malaysia and consequently cause loss of life or property. Due to that, many road accident data have been collected by highway concessionaries or build-operate-transfer operating companies in the country meant for coming up with proper counter measures. Several analyses can be done on the accumulated data in order to improve road safety. In this study, the reported fatal road accidents cases in North South Expressway (NSE) from Sungai Petani to Bukit Lanjan during 2011-2014 period is analyzed. The aim is to identify spatial pattern and hot spots across this longest controlled-access expressway in Malaysia as hotspot represents the location of the road which is considered high risk and the probability of traffic accidents in relation to the level of risk in the surrounding areas. As no methodology for identifying hotspot has been agreed globally yet, hence, this study helps determining the suitable principles and techniques for determination of the hotspot on Malaysian highways. Two spatial analysis techniques are applied, Nearest Neighborhood Hierarchical (NNH) Clustering and Spatial Temporal Clustering, using CrimeStat® and visualizing in ArcGIS™ Software to calculate the concentration of the incidents and the results are compared based on their accuracies. Results identified several hotspots and showed that they vary in number and locations, depending on their parameter values. Further analysis on selected hot spot location shows that Spatial Temporal Clustering (STAC) has a higher accuracy index compared to Nearest Neighbor Hierarchical Clustering (NNH). Several recommendations on counter measures have also been proposed based on the details results.

Key words: Spatial analysis, fatal accidents, hot spots, calculate, several, compared

INTRODUCTION

Road accidents constitute a major public health crisis in the world. According to Prasannakumar *et al.* (2011), worldwide road accidents are still one of the leading causes of death. Every year the number of deaths due to road accidents is reported to be increasing (WHO., 2004) reported that, the number of people killed in road accidents each year is estimated almost 1.25 million while the number of injured could be as high as 50 million. Worst still, the number of road accidents and injuries is expected to increase by 65% between 2000 and 2020.

Without any proper initiatives and public and government efforts this issue seems to become a decisive global problem. Currently according to global status report on road safety 2015 states that road traffic injuries are estimated to be the 9th leading cause of death globally. Hence, it is predicted to become the seventh leading cause of death by 2030. In addition, 90% of road deaths occur in low and middle income countries while these countries accounted 82% of the total world's population. Road accidents may happen in a second but the consequences may last for the day, months and years or for the rest of life. Undoubtedly, road accidents have the devastating impact not only on emotional and physiological but also on economics. For instance, road accidents may give an economic burden for a family to support the medical costs of the victim. There are a large number of road users involved in the road accidents recover from their injuries but some of them might suffer from the permanent disability. A study by Kareem (2003) on Malaysia road accident situation stated that the psychological sufferings are often intense, lasting and even permanent. The victims may generate somatic

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illnesses which worsen this psychological distress, creating a vicious circle. Some examples of long-term consequences are loss of memory, cerebral atrophy, hydrochepalus, loss of any part of the body, paresis, paralysis and depression which worsen their remaining life period. With the rapid development in Malaysia's economy, the issue of road safety becomes increasingly important. According to Malaysian Institute of Road Safety Research (MIROS) (MIRSR., 2012), in 2014 the total number of road accidents was 476,196 with the number of road deaths was 6,676 cases, seriously injured was 4,432 cases and slightly injured was 8,598 cases. Malaysia has been ranked the 8th in fatalities of road crashes in the mortality from road crashes in 193 countries report.

In addition to that Malaysia Road Transports Department (RTD) (WHO., 2015), reported that in 2014, Malaysia lost RM 9 billion due to road deaths. On average, more than ten billion ringgit has been lost due to road accidents every year. It is also reported that, the highest fatalities by the age group in Malaysia are among young persons aged 16-25 years old. This study focuses on determining the hotspots where the road accidents ended in fatalities along the North-South Expressway (NSE).

The NSE is the longest controlled-access expressway in Malaysia with the total length of about 772 km (480 mile) running from Bukit Kayu Hitam in Kedah near the Malaysian-Thai border (connects with Phetkasem Road (Route 4) in Thailand) to Johor Bahru at the Southern portion of Peninsular Malaysia and to Singapore. The expressway links many major cities and towns in Western Peninsular Malaysia, acting as the 'backbone' of the West coast of the Peninsula. It is also known as PLUS Expressway, named after the highway's concessionaire, Projek Lebuhraya Utara Selatan Berhad (North South Expressway Project, abbreviated as PLUS. The company has changed its name to Projek Lebuhraya Usahasama Berhad (PLUS) which is a subsidiary of PLUS Malaysia Berhad (PMB).

This expressway passes through 7 states on the Peninsula: Johor, Malacca, Negeri Sembilan, Selangor, Perak, Penang and Kedah. It provides a faster alternative to the old Federal Route 1, thus, reducing travelling time between various towns and cities. On top of its providing convenience to travelers there were a lot of accidents reported along the expressway. For example, the morning accident on 24th June, 2016 along the 406th km of the North-South Expressway brought traffic on both sides to a standstill has involved 16 vehicles which resulted in a man losing his wife and daughter (SPH., 2016). In a post on the Star Media Radio Traffic page, it was reported that the accident took place at 269.1 km of the North-South Expressway from the Seremban rest area Southbound Bandar Ainsdale on Thursday, 9th June 2016 afternoon. The fatal accident involved 2 cars at 269.1 km from the Seremban rest area Southbound Bandar Ainsdale and has caused the traffic to remain at a 3 km crawl until late afternoon. As mentioned earlier, road accidents are becoming a global health crisis and as such, require comprehensive measures to prevent them including a better understanding of the social impacts of road-related deaths and injuries. Hence, this study intends to analyze the spatial pattern of road accidents along the NSE and identify the accidents hot spots as an effort to propose for suitable preventive measures. Number of studies has been carried out across the world to analysis spatial pattern of road accidents (Xie *et al*., 2015; Truong and Somenahalli, 2011; Chainey *et al*., 2008) in several countries.

MATERIALS AND METHODS

This study examines monthly reported road accidents involving all types of vehicles that occurred along North-South Expressway (NSE) starting from Sungai Petani to Bukit Lanjan from 2011-2014. The data is obtained from PLUS Expressway Berhad that includes accident locations (in terms of kilometer), the month, date, day, time, vehicle involved, causes of accident, collision type and injury type. We divided the length of the expressway, along Sungai Petani to Bukit Lanjan into six sections as described in Table 1. Descriptive analysis on road accidents at each section is presented to observe the pattern.

In order to identify the hotspots, two methods nearest neighbor analysis and spatial temporal clustering analysis are considered.

Nearest neighbor analysis: Nearest Neighbor Index is the ratio of the observed distance divided by the expected distance. If the index value shows <1, it means that the pattern of incident exhibits clustering and if the index is greater than 1, it means that the incident trend is toward dispersion. In nearest neighbor analysis, it tests whether the pattern of incident is randomly distributed or not and calculate the Z score:

$$Z = \frac{\text{Avg. nearest neighbor-Expected Avg. nearest neighbor}}{\text{Standard deviation}}$$

Table 1: Location and section of study area

Sections	Location	Distance (km)
N3	Sungai Petani to Jawi	54.90
N4	Jawi to Cangkat Jering	56.80
N5	Cangkat Jering to Ipoh	55.40
C1	Ipoh to Bidor	64.40
C2	Bidor to Tanjung Malim	59.70
C3	Tanjung Malim to Bukit Lanjan	60.30

Nearest neighbor index is calculated as follows:

$$\text{Nearest neighbor index} = \frac{\text{Avg. nearest neighbor}}{\text{Expected Avg.: nearest neighbor}}$$

Nearest Neighbor Hierarchical (NNH) clustering: In order to identify the density of road accidents occurrence or the hot spots, predefined threshold values need to be determined. Similarly, the number of accidents n_{min} considered to be within one cluster also needs to be predetermined. Using CrimeStat Software, 1 km have been set up as a threshold distance while the minimum number per clusters n_{min} is 10. At the same time, NNH results are given with their severity value which is the number of accidents located in the boundary of a cluster, user should visualize clusters with regards to severity values to identify most important areas.

Spatial Temporal Clustering Analysis (STAC): STAC is one of the widely used methods in detecting hot spot in the entire study area. Using STAC, the hot spots is identified according to its shape whether triangular or rectangular. In most previous studies it is suggested to use rectangular if the analysis area has most regular pattern while the triangular pattern is most suitable for the area which generally has an irregular pattern. STAC places a circle on every node, then it will count the number of accident which falling within each circle and ranks the circle in descending order. The X and Y coordinates of any node with at least two incidents within the search radius are recorded, along with the number of data points found for each node.

RESULTS AND DISCUSSION

Descriptive statistics: Figure 1 shows the trend of accidents in North South Expressway from years 2011 to 2014. The figure represents the increasing number of accident from 2011 to 2012 but the number of accident decreased from year 2012 to 2013. While from 2013 to 2014 it shows a slightly upward trend. Figure 2 shows from 2011 to 2014 sections C3 (Tanjung Malim to Bukit Lanjan) recorded 30.5% of total accidents, the highest number of road accident compared to the other sections.

This study remains the record of having the highest cases of road accident from 2011-2014. While the lowest number of road accident is section N3 which is from Sungai Petani to Jawi which contributed only 6.7% of the total number of accident in all sections.

The severity rating of the vast majority of road accident across North South Expressway is described in Fig. 3.

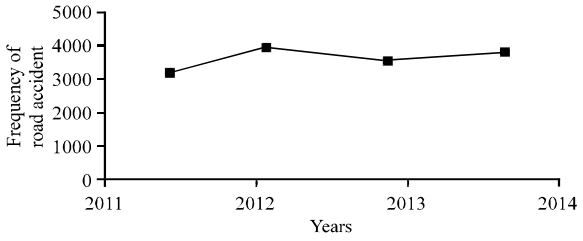

Fig. 1: Road accident trends in Malaysia from 2011-2014

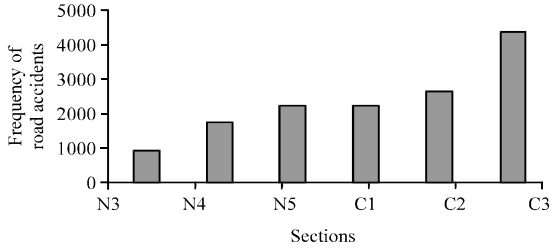

Fig. 2: Road accident trends by sections from 2011-2014

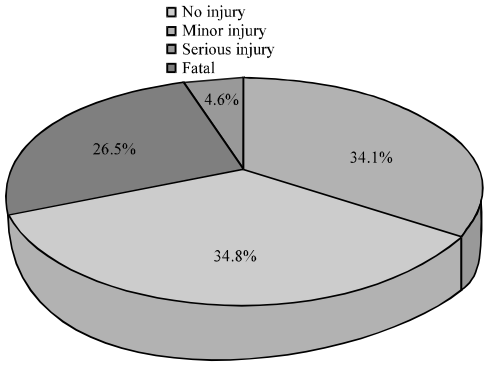

Fig. 3: Road accident severity

Table 2: Nearest neighbor index result

Variables	Values
dfMean nearest neighbor distance (m)	3.84320
Expected nearest neighbor distance (m)	758.807
Nearest neighbor index	0.00506

Test statistic (Z): -237.6788; p-value one tail: 0.0001

Nearest neighbor analysis result: Table 2 shows that the road accident cases across North South Expressway (NSE) are having a clustered distribution. This is because the Nearest Neighbor Index is 0.00506 which is <1. Besides that, the p-value also shows that it less than a = 0.05, thus, we reject null hypothesis and it goes to the conclusion where the road accident exhibits a clustering pattern.

Nearest neighbor hierarchical clustering method for fatalities accident: Results show that total of 15 hotspots for fatalities accidents are found. The number of accidents

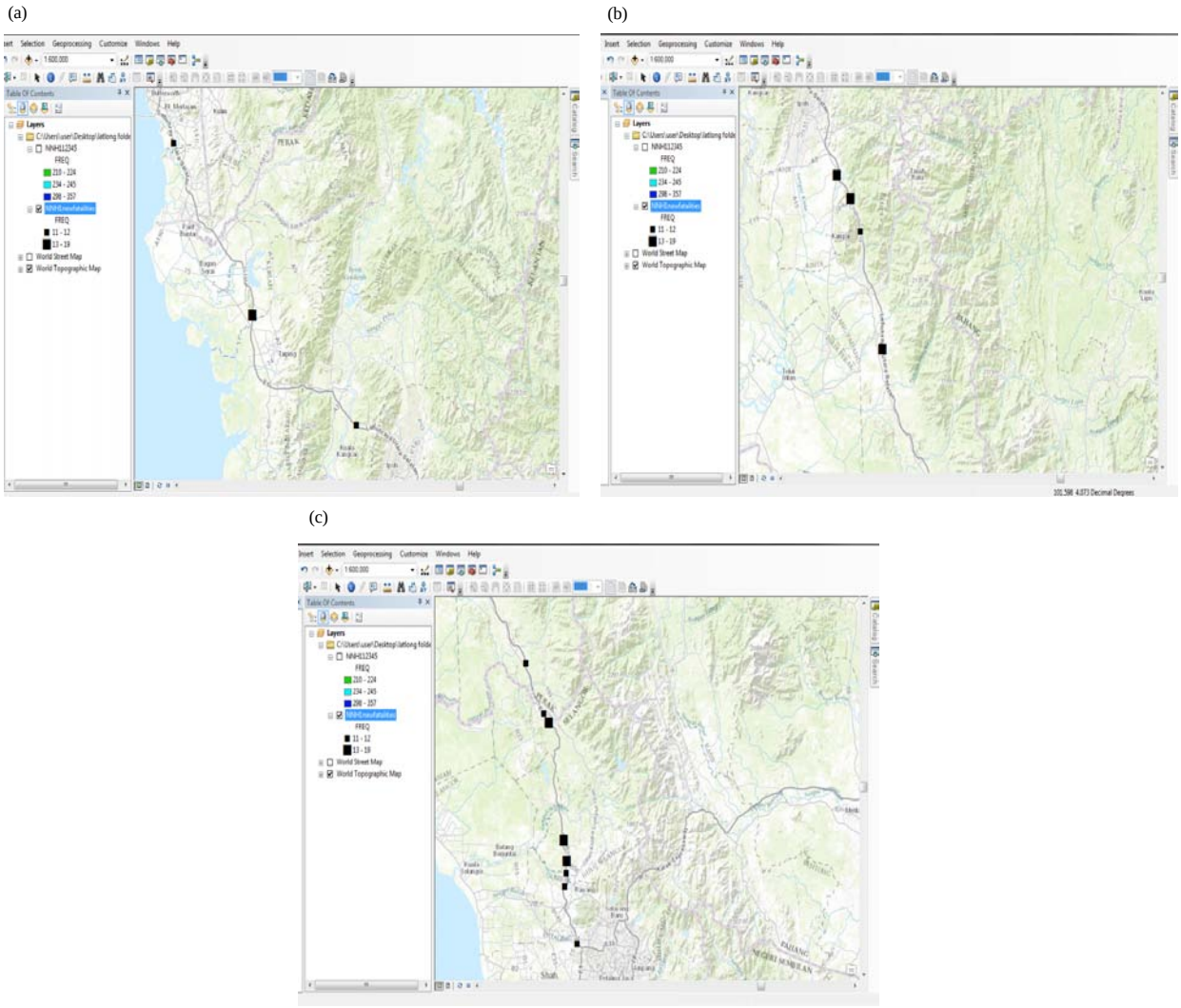

Fig. 4: a-c) Hot spot area of fatalities using NNH

with severities in each hotspot varies from 11-19 accidents. There is one hotspot with the severity of 19 accidents. It was located at the section C1 which is from Ipoh to Bidor. Also, there are four hotspots with 15 severe accidents which are located randomly. There are two hot spots constituted from 14 accidents both are located on section C3 (Tanjung Malim to Bukit Lanjan). Besides, there are 3 hot spots calculated with the severities of 12 accidents. All these fatality hot spots with respect to their severity values are visualized with topographic mapping technique which can be seen in Fig. 4. These hotspots are randomly located with no specific pattern, yet it tends to be closer to the city or close to corner of the road and some of these hotspots are found at the corner of highway.

Spatial temporal clustering method for fatalities accident: Sensitivity analysis has been done to determine the suitable minimum number of fatal accidents and figured that it should be a small number. For example, the minimum number per clusters is originally selected to be more than 5, however, the analysis cannot found any clusters. Hence, n_{min} is set to be 5 and the search radius is set as 0.5 km

Using the fatalities data, the result of hot spot is as follows; total of 12 hot spots found across the highway with the highest number of recorded accident is 14 per clusters and the lowest is 5 accidents per clusters. Figure 5 visualizes the hot spots in ArcGis. It shows that again, C3 section which is Tanjung Malim to Bukit Lanjan recorded the highest number of hot spots. This could be

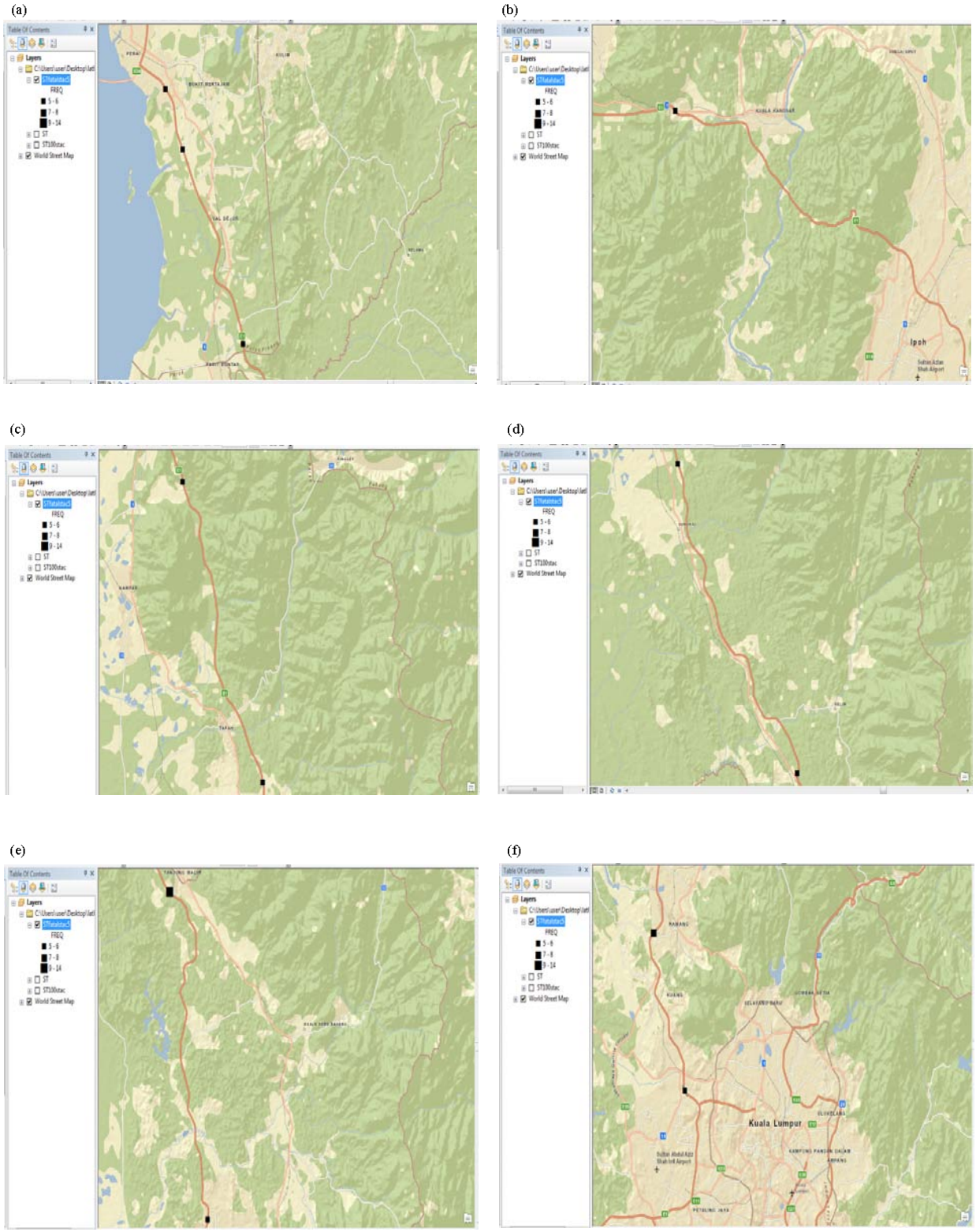

Fig. 5: a-f) Hot spot areas fatalities using STAC

because of road condition compared to other sections which have a lot of corner and structure of the road itself.

CONCLUSION

Overall, the pattern of road accident on North South Expressway (NSE) resulted in clustering pattern which means that the accident was grouped in one location. The number of fatality accident hot spot is crated with the threshold distance of 1 km which is used in highway traffic safety as well. Both methods took into consideration the number of fatality accidents is few, n_{min} = 10 for NNH and n_{min} = 5 for STAC. Meanwhile, the number of accidents found in clusters varies between 11-19. For all results, it can be said that the most hot spots are located in C3 sections which is from Tanjung Malim to Bukit Lanjan where along the sections is a 3 road lane. Hence, traffic safety should be aware of this situation since, nearly half of the total calculated hot spots are seen in this study.

RECOMMENDATIONS

It is advisable to further research to add more of hot spot technique methods such as Kernel Density Estimation (KDE), k-means clustering, Getis-Ord Statistics and Moran's Index. Besides that, the study can be divided into another sub group such as collision type, injury type or vehicles involved. Compared to other studies which consider the network design such as roundabout and intersections, this study cannot take any design type in consideration since the highway is a straight road network. However, the number of lanes or road types could be used to understand the relationship between the hot spots and roads. Speed status of the particular road segments can be used when analyzing the hot spots.

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