Spatial And Temporal Pattern of Road Accidents and Casualties in Peninsular Malaysia

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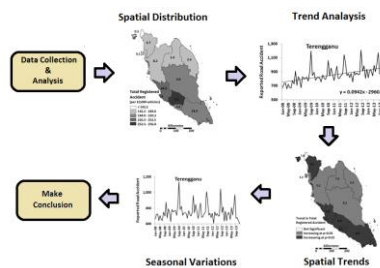
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Graphical abstract

Abstract

Road traffic accidents are often found to follow some spatial and temporal patterns as the factors that influence road accident changes with space and time. Knowledge on spatial and temporal variability of accident can be helpful for optimizing resources in order to improve traffic security management. The objective of the present study is to assess the spatial and temporal variation in the incidence of road traffic accidents and casualties across the states of peninsular Malaysia. Recent trends in number of accidents, casualties and fatalities are also accessed using non-parametric statistical method. The results show more accidents but lower fatalities in more urbanized and developed states, and lower accident levels but more serious fatalities in less urbanized or developed states of Peninsular Malaysia. Trend analysis reveals increasing number of accidents, but decreasing number casualties in recent years in most of the states of Peninsular Malaysia. The temporal analysis shows clear seasonal pattern in accident in some states of Malaysia. Most of the accidents are found to occur in festive month of Hari Raya Puasa festival followed by the month of mid-year school holiday. It is expected that the finding of the study will help in making recommendations in order to improve road safety and reduce road traffic accident in Malaysia.

Keywords: Traffic accident, GIS, trend, spatio-temporal variation

1.0 INTRODUCTION

Road accident depends on various mechanical, behavioral, and environmental factors [1]. These factors vary in space and time. Therefore, the incidence of road accidents and fatalities also vary at both spatial and temporal scales [2]. Land use pattern, types of road network, local business and activity pattern influences the accident risk in an area [3]. Cutter [4] reported that analysis of spatial distribution of road accident is important in order to assess the impacts of influential factors. Besides that geography such as, rural-urban differences, climate, topography, etc. often define the spatial pattern of road accident. In urban areas, there are more accidents, lower degree of injury while in rural areas, there are lower number of accidents but more serious fatalities [5]. The number of road accidents also varies with time. The

road accident often found to follow a pattern with the days of the week or the months of the year. Therefore, that road accident incidence and road accident risk changes continually with time and space. It is of vital importance to analyze road traffic accidents in both spatial and temporal scales in order to improve traffic security management [1].

Number of studies has been carried out across the world to analysis spatial and temporal pattern of road traffic accident. Zhang *et al*. [6] reported that zonal factors such as traffic behavior, land use, transportation facility, and demographic features define the spatial variability of accident. They mentioned that spatial variability of road accident can be used for deciphering safety measures and optimizing resources for enforcement of safety regulations for reduction of road accident. Mohan *et al*. [7] reported that spatial and temporal trends of

road accident can be used by administrators to devise effective strategies for accident prevention by concentrating on the high-risk areas, thereby optimizing the use of available personnel and resources. De Andrade *et al*. [8] mentioned that spatial assessment of accident data helps in identify the accident prone zones and environmental characteristics, which regulatory agencies could make use to plan strategies to reduce accident and support life-saving policies. Similarly, temporal or seasonal analysis of road traffic accident can help to identify the peak accident time or season for adopting necessary preventive measures. Chaney and Kim [9] studied the temporal variations in collisions occur at higher rates in Ohio (USA) and reported that collision rates in summer is most common. They concluded that dissemination of temporal variation of collisions to local city authorities and advocacy groups can help to reduce accident. Carrick *et al*. [10] reported that temporal analysis of accident provides opportunities to optimize the time of traffic enforcement.

Traffic accidents rank fifth among the leading cause of deaths in Malaysia [11]. According to Road Transport Department (RTD) of Malaysia, the country lost RM9 billion due to road deaths in 2014. On average, the country is burdened with more than ten billion ringgit of losses due to traffic accidents every year. Malaysia has taken number of initiatives in last two decades to grow public awareness of road safety. National safety target and interventions was designed in 1995 to both prevent and reduce traffic accidents as well as to reduce injuries during and after accidents. Strategies were categorized into exposure control, crash prevention, crash reduction, behavior modification, injury control and post injury programs. The safety intervention measures were able to significantly reduce ($p<0.05$) traffic deaths and offset the upward fatality trend in Malaysia.

However, the initiatives were not completely successful to reduce the accident and fatality rate to desire level. It was identified that different intervention measures such as automatic enforcement system, new drivers training system, and exclusive motorcycle lanes were not fully implemented. Some of the interventions were implemented but failed to give intended results such as rear seat belt law, motorcycle helmet initiatives, and community based programs. Besides that outcomes of some of the measures were very slow such as road safety education in school, social marketing strategies. In 2010, framework for the 2011-2020 road safety plan was designed with desired outcomes of safer roads and mobility, safer vehicles, safer road users, post-crash management, etc. Major target of the framework was to reduce accident rate by 6% per year. However, Malaysia is still considered as one of the most dangerous countries in term of road safety. The road fatalities currently stand at 25 deaths per 100,000 population, a value which is higher than India (19.9) and China (20.5) [12]. This indicates that Malaysia needs to adopt more initiatives to improve road safety and reduce road accident.

The major objective of this study is to assess the spatial and temporal variation in the incidence of road traffic accidents and casualties as well as their trends in recent years across the 11 states in peninsular Malaysia. It is expected that the present study will help in making recommendations in order to improve road safety and reduce road accident in Malaysia.

2.0 DATA AND METHOD

2.1 Data and Sources

State-wise data of registered vehicles, road traffic accident, major and minor causalities, and fatalities were collected from statistical report of road accident (2008-2013) published by Laporan Perangkaan Kemalangan Jalan Raya (Polis Diraja Malaysia). The obtained data were analyzed using various statistical approaches. The methods used in the present study are discussed below in details.

2.2 Spatial Variability and Changes

Geographical Information System (GIS) was used in the present study for visualization of spatial variability of accident and fatality and their trends in Malaysia. GIS maintains the spatial location of sampling points, and provides tools to relate the sampling data through a relational database [13]. Therefore, GIS is widely used in visualization and spatial analysis of different kinds of data. Driss *et al*. [14] reported that GIS enables a spatial visualization of the degrees of exposure to road accident's risk and therefore, can be used as road safety tool for identifying risk factors related to the characteristics of the road. Yalcin and Duzgun [15] used GIS as a management system for spatial accident analysis.

2.3 Temporal Variability and Changes

Considering the short time period of accident data, non-parametric Mann–Kendall trend test [16, 17] was used to detect the trend in accidents and causalities. Significance level of 0.01 and 0.05 were taken as thresholds to classify the significance of positive and negative trends. Sen's slope method [18] was used to determine the magnitude of change. The Mann–Kendall test [16, 17] is useful in determining the possible existence of statistically significant trends at different confidence levels when the number of data points is less and the data distribution is unknown. On the other hand Sen's Slope method gives a robust estimation of change from a time series of equally spaced data, even when the number of data points is very less [19].

In Mann-Kendall (MK) test the data values are evaluated as an ordered time series. If x_1 , x_2 , x_3 ..... x_i represent *n* data points where x_j represents the data point at time *j*, then *S* is given by,

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k)$$

where: $sing(x_j - x_k) = \begin{cases} 1 & if \ x_j - x_j > 0 \\ 0 & if \ x_j - x_j = 0 \\ -1 & if \ x_j - x_j < 0 \end{cases}$ 　　(1)

Normalized test statistic Z is computed as follows:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAS(S)}} & if \ S > 0 \\ 0 & if \ S = 0 \\ \dfrac{S+1}{\sqrt{VAS(S)}} & if \ S < 0 \end{cases} \qquad (2)$$

The null hypothesis of no trend is rejected at p=0.01, if $|Z| > 2.575$; and at p=0.05, if $|Z| > 1.96$.

Sen's method proceeds by calculating the slope as a change in measurement per change in time,

$$Q' = {x'_t - x_t}\Big/{t' - t} \qquad (3)$$

where, Q' is slope between data points $x_{t'}$ and x_t; $x_{t'}$ is data measurement at time t', and x_t is the data measurement at time t. Sen's estimator of slope is simply given by the median slope,

$$Q = \begin{cases} Q'_{[\frac{n+1}{2}]} & if \ N \ is \ odd \\ \left(Q'_{[\frac{N}{2}]} + Q'_{[\frac{n+1}{2}]} \right)/2 & if \ N \ is \ even \end{cases} \qquad (4)$$

where, N is the number of calculated slopes.

3.0 RESULTS AND DISCUSSION

3.1 Spatial Distribution of Road Accident

The state-wise distribution of total number of registered vehicles, total number of registered accidents, major casualties, minor casualties and deaths based on years 2008-2013 are presented in Figure 1. In the maps, data of federal territory of Kuala Lumpur is included in Selangor. Description of spatial distribution of registered vehicles, accidents and casualties are given below. In the all the maps presented in Figure 1, the actual numbers are given as legend and the percentage to total is given as level. For example, in the map of registered vehicles (Figure 1a), the number of registered vehicles is give as legend and percentage of registered vehicles in a state to total number of registered vehicles in Malaysia is given a

level. Kelantan is represented by white color in the map (Figure 1a). It means that total number of registered vehicles in Kelantan is in the range of 655.3 to 872.7 thousands. The level 3.0 means that 3% of total registered vehicles are registered in Kelantan.

State-wise distribution of registered vehicles in Malaysia (Figure 1) shows that more than one-third (37.8%) vehicles are registered in Selangor (including federal territory of Kuala Lumpur and Putra Jaya). Johor is in second in term of registered vehicles (14.9%), which is followed by Penang (11.3%) and Perak (9.8%). Percentages of registered vehicles in other states are in the range of 3 to 6%, except Perlis (1%) which is in the last of the list in term of registered vehicles.

Figure 1(b) shows the state-wise distribution of percentage of accidents to total accident in Malaysia follows the similar spatial pattern of registered vehicles. Maximum number of registered road accident occurs in Selangor (44.5%). Johor is in second (14.4%), which is followed by Penang (9.1%) and Perak (8.2%). However, the spatial pattern of number of road accident per 10,000 registered vehicles is very much different from spatial pattern of registered vehicles. Registered number of road accidents per 10,000 vehicles was found highest in Negeri Sembilan (256 per 10,000 vehicles). Though the number of accident in term of percentage of total accident in Malaysia was found very high in Selangor and Johor, numbers of accidents per 10,000 vehicles in those states were found similar to Melaka and Pahang. Overall, number of road accidents per 10,000 vehicles was found higher in the south compared to north.

The most interesting patterns were observed in number of casualties and death due to road accident. Both the major and minor casualties in terms of both percentages to total in Malaysia and number per 10,000 registered vehicles (Figures 1(c) and (d), respectively) were found higher in Kelantan, Perak and Kedah compared to Selangor, Johor and Pulau Pinang, which have the high number of registered vehicles like. In case of number of deaths due to road traffic accident (Figure 2(e)), it was found that the percentage of death to total number death was higher in Selangor (21.4%) and Johor (17.9%). However, when the number of death per 10,000 vehicles was compared, more or less similar pattern like casualties was observed. Higher number of deaths per 10,000 vehicles was found in Kelantan and Pahang.
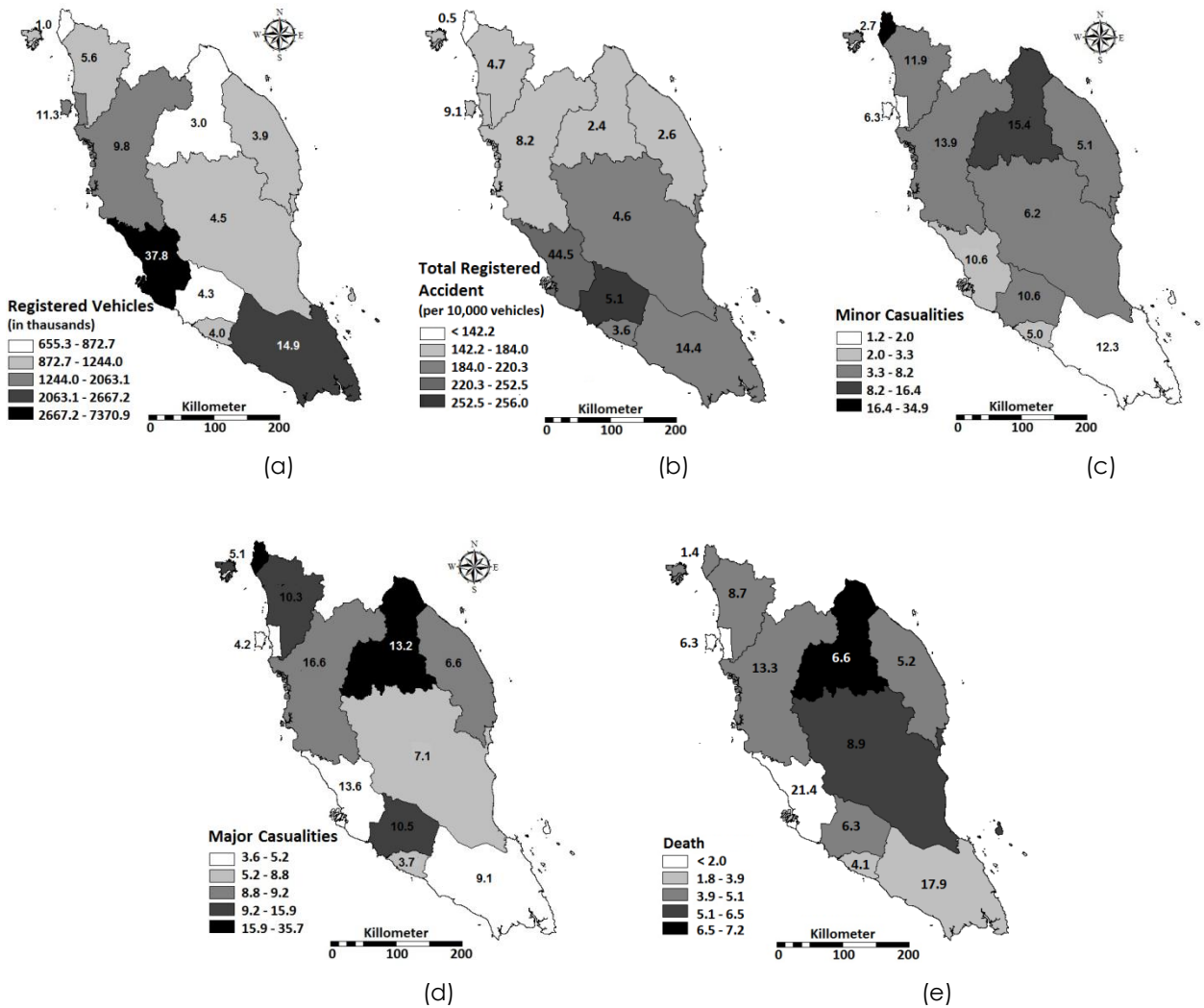
Figure 1 Spatial distribution of (a) registered road vehicles; (b) registered road accident; (c) minor casualties; (d) major casualties; and (e) accident death in peninsular Malaysia

Kelantan can be categorized as least in term of number of registered vehicles. Only 3% of total registered vehicles in Malaysia are registered in Kelantan. Number of registered road accident in Kelantan is also less compared to other states like Selangor, Johor, Negeri Sembilan, Melaka, etc. Only 2.4% of total registered road accidents in Malaysia occurs in Kelantan. However, casualties and fatality due to road accident is much higher in Kelantan compared to any other states of Malaysia. Similar results were found for Perlis, which contains only 1% of total registered vehicles in Malaysia. Only 0.5% of total registered road accidents occur in Perlis. However, percentages of minor casualties, major casualties and deaths due to road accident in the state are 2.7, 5.1 and 1.4%, respectively. Casualties and death per 10,000 vehicles are also very high in Perlis. This indicates that the most fatal accidents in Malaysia occur in Kelantan and Perlis. The states Kelantan and Perlis are less urbanized and developed compared to other states of peninsular Malaysia. Post-accident care

services are less in those states compared to other states. This may be one of the causes of more serious casualties in those states. Literacy rate in Kelantan is lowest in Peninsular Malaysia. As the awareness is directly related to literacy, it can be remarked that road safety awareness is lowest in Kelantan in Peninsular Malaysia. This emphasizes the need of growing awareness of road safety in Kelantan.

When all the maps in Figure 1 were compared together, it was observe that number of registered vehicles and number of registered road accidents are more in developed states of peninsular Malaysia like Selangor and Johor. But the numbers of casualties and fatalities are more in less developed states like Kelantan and Perlis. This again indicates that road accident casualties and fatalities do not only depend on number of registered vehicles. Other factors, like awareness, enforcement of law, implementation of safety measures, post-accident care, etc are very important to reduce casualties and deaths from road accident. The study revealed that more developed

and urbanized states experience more accidents but lower fatalities. On the other hand, lower accident levels but more serious fatalities are observed in less urbanized or developed states of peninsular Malaysia.

3.2 Spatial Distribution of Trends

Malaysia has taken number of steps to increase road safety awareness. The Road Safety Education (RSE) Program was introduced in 2007 as a long term measure to reduce the high number of road accidents and deaths. It has been reported that awareness of road safety, understanding of the law, and recognition of road signs have been grown among people [20]. In the present study, the recent trends (2008-2013) in

road accidents, casualties and fatalities were assessed to understand the state-wise spatial distribution of the changes in accident and casualties in Malaysia. The recent trends in registered vehicles, registered accidents, minor casualties, major casualties, and accident deaths are given in Figure 2. The number in the figure denotes change in percentage. The color shade indicates the significance of trend in a state. Significant changes are presented by deep shades in the figures.
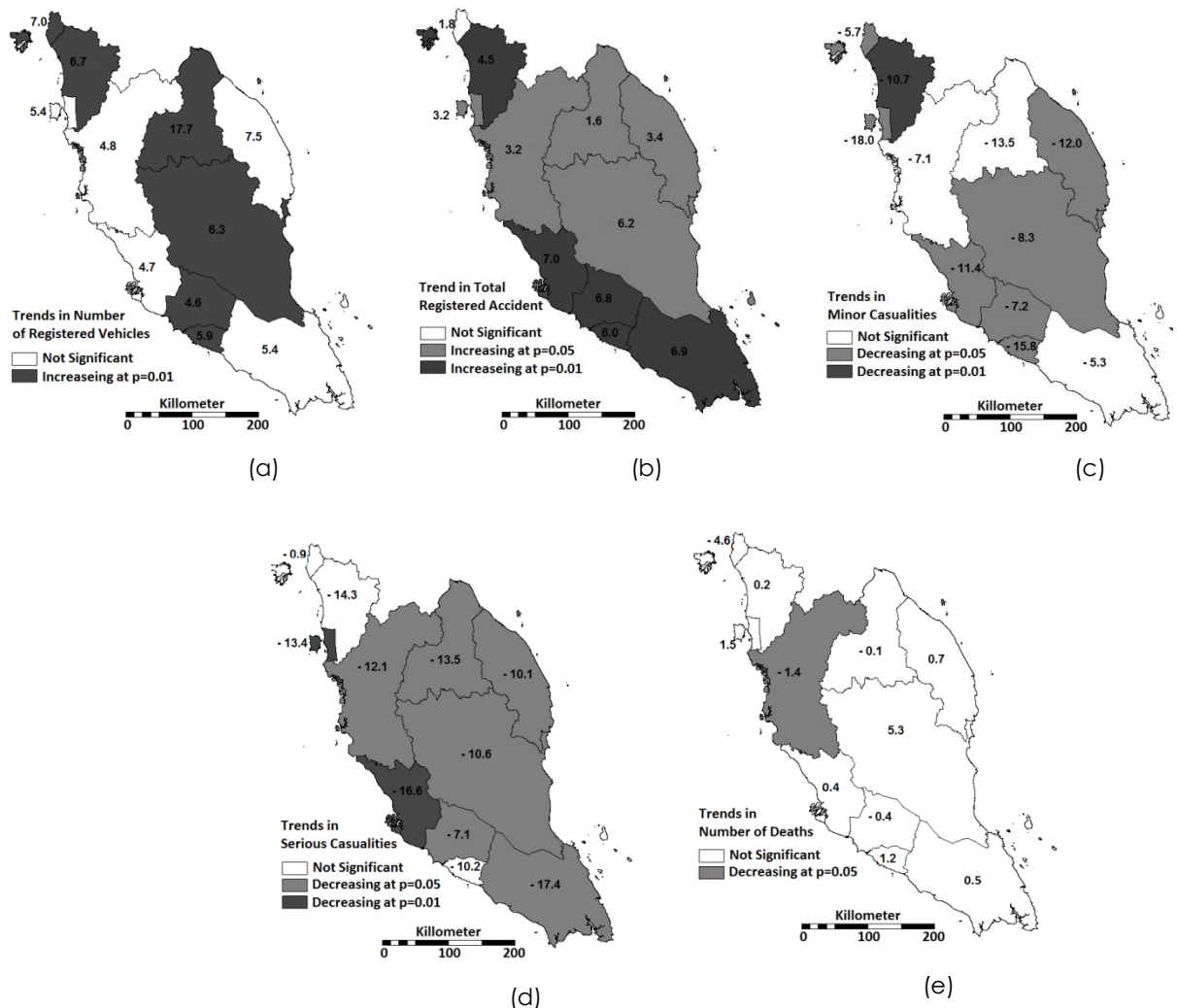

Figure 2 Spatial distribution of the trend in (a) registered road vehicles; (b) registered road accident; (c) minor casualties; (d) major casualties; and (e) accident death in peninsular Malaysia

The spatial distribution of the trends in number of registered vehicles over the time period 2008-2013 shows that number of vehicles is increasing significantly in Kelantan, Kedah, Perlis, Pahang, Melaka and Negeri

Sembilan. When compared with Figure 1(a), it was found that number of registered vehicles is increasing significantly in the states that have less number of vehicles. The increases were not significant in Selangor,

Johor and Penang, which already have major share of total registered vehicles in Malaysia.

Figure 2(b) shows that the number of registered accident has increased significantly in all states of peninsular Malaysia except Perlis. The increase is significant at 99% level of significance in the states of Selangor, Negeri Sembilan, Melaka, Johor and Kedah. On the other hand, it has increased significantly at 95% level of confidence in the states of Pahang, Perak, Kelantan and Terengganu. Maximum increase of registered road traffic accident was observed in Selangor (7%), followed by Johor (6.9%), Negeri Sembilan (6.8%), Pahang (6.2%) and Melaka (6.0%).

Though the number of registered road accident has increased in almost all states of peninsular Malaysia, number of casualties and fatalities has decreased in most of the states over the time period 2008-2013. Figure 2(c) shows that minor casualties has decreased significantly in Selangor, Negeri Sembilan, Melaka, Pahang, Terengganu, Pulau Pinang and Kedah. The maximum decrease was observed at a rate of 18% in Pulau Pinang and 15.8% in Melaka. Major casualties (Figure 1(d)) have decreased in most of the states of Peninsular Malaysia significantly. It is decreased at 99% level of significance in the states of Selangor and Pulau Pinang, which are among the most accident prone states of Malaysia. Maximum decrease of major casualties due to road accident over the time period 2008-2013 was found in Johor (17.4%) followed by Selangor (16.6%) and Pulau Pinang (13.4%).

The trends in number of death due to road traffic accidents in Peninsular Malaysia revealed significant (95% level) decrease only in Perak over the time period 2008-2013. It indicates that in spite of number of initiatives taken to reduce fatalities due to road accident in Malaysia, number of deaths due to road traffic accident has not reduced significantly in almost any state of peninsular Malaysia. The states like Selangor where maximum number vehicles registered and maximum number of accident occurs, accidents were found to increase but the number of casualties was found to decrease over the time period 2008-2013. Similar trend was found in state like Kelantan where number of casualties per 10,000 vehicles is very high. The number of registered road traffic accident was found to increase, but number of casualties is found to decrease in Kelantan. It indicates that scenarios of casualties and deaths are different among developed and less developed states, but the trends in number of accident and casualties are similar in both cases. It means that government initiatives to reduce accident and casualties have similar effect in all the states.

3.3 Temporal Distribution of Accident

It is well recognized that number of accident within a year often follows some specific pattern. For example, more accident occurs during festival period, school holidays, winter icing season, etc. Knowledge on temporal pattern of accident can be help to plan necessary action to reduce accident. Therefore, temporal pattern of accident in different states of peninsular Malaysia was also analyzed in this paper.

Temporal trend in data often preclude the seasonal pattern exist in data. Therefore, to assess the seasonal pattern of accident in different states of Malaysia, the trend in accident time series data was first removed. For this purpose, a regression equation relating annual accident and time period was developed. The equation was then used to detrend the accident time series. The detrending process for Terengganu is shown in Figure 3. A regression equation (shown in Figure 3) was first developed, which relates the number of total accident (y) with time (x). The equation was then used to detrend the time series of accident data. The detrended accident time series for Terengganu is shown in Figure 4 along with the average monthly distributions of accident in different states of peninsular Malaysia.
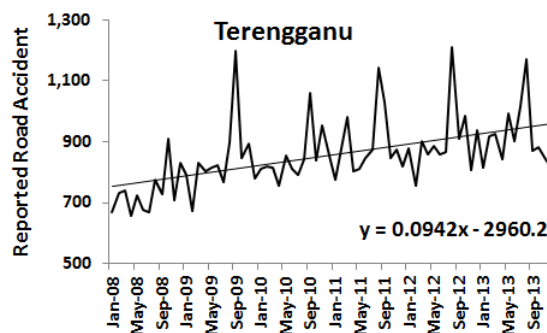

Figure 3 The process of de-trending monthly total registered accident in Terengganu

Figures show that accident in the east coastal region of Malaysia follows a clear pattern. The pick months of accident in different states of Malaysia are given in Table 1. The Figure 4 and Table 1 show that the accident always follows a pick during festival month (Hari Raya Puasa). On the other hand, the accident in the west coastal regions does not follow any specific pattern. Table 1 show that maximum number of accident in Malaysia occurs during festival months. In all the years under study, maximum accident occurred in festival months in most of the states. In years 2008, maximum number of accidents occurred in October (month of Hari Raya Puasa) in all the states. In year 2009 and 2010, maximum accident occurred in September in most of the states as Hari Raya Puasa was in the month of September. Similarly, in years 2011-2013, maximum accident occurred in August in most of the states as Hari Raya Puasa was in the month of August. However, the table shows that the number of accident during festival months started to decrease or surplus by accident in other months in recent years in some states, particularly those are located in the west coast of Malaysia.
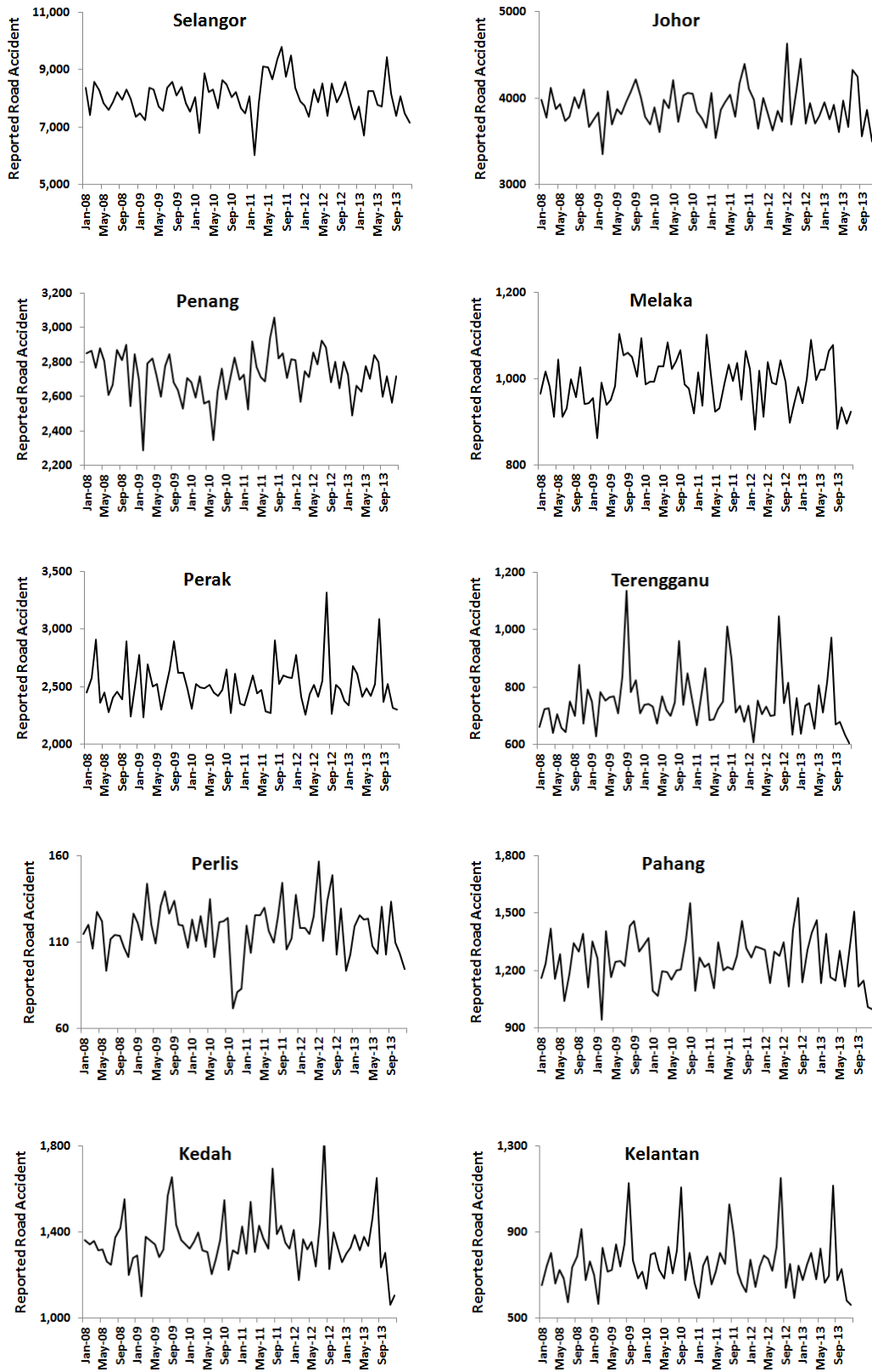
Figure 4 Monthly distribution of registered accidents in different states of peninsular Malaysia

For example, no seasonal pattern in accident can be observed in recent years for the states like Selangor, Johor and Pulau Pinang. The table also shows that the month having the second highest accident in most of the states of peninsular Malaysia is May, which is the month of mid-year school holiday.

Table 1 Peak accident months during 2008-2013 in different states of peninsular Malaysia

State	Year					
	2008	2009	2010	2011	2012	2013
Johor	Oct	Sep	May	Aug	May	Jul
Kedah	Oct	Sep	Sep	Aug	Aug	Aug
Kelantan	Oct	Sep	Sep	Aug	Aug	Aug
Melaka	Oct	Dec	Jun	Dec	Aug	Aug
Pahang	Oct	Sep	Sep	Aug	Aug	Aug
Perak	Oct	Sep	Sep	Aug	Aug	Aug
Perlis	Dec	Mar	May	Sep	May	Sep
Pulau Pinang	Oct	Aug	Nov	Aug	Jul	Jul
Selangor	Oct	Aug	Mar	Aug	Oct	Jul
Terengganu	Oct	Sep	Sep	Aug	Aug	Aug
N/Sembilan	Oct	Aug	Aug	Nov	Aug	Aug

4.0 CONCLUSION

The results of the study conducted for the assessment of the spatial and temporal variation accidents, casualties, and fatalities as well their trends in different states of peninsular Malaysia are presented in this article. Non-parametric statistical approaches were used to assess the trends and estimate the magnitude of change. GIS was used to visualize the results. The results revealed more accidents but lower fatalities in urbanized and developed states, and lower accident levels but more serious fatalities in less urbanized or developed states of Peninsular Malaysia. Increasing number of accidents but decreasing number casualties has been notices in recent years in most of the states of Peninsular Malaysia. Accidents in most of the states of peninsular Malaysia were found to occur in festival month of Hari Raya Puasa. The obtained information can be used to develop effective strategies for accident prevention by concentrating on the high-risk states during peak accident period by optimizing the use of available personnel and resources. The information can also be used to plan strategies to reduce accident and fatalities.

The present study is conducted based on available data on hand. The study can be repeated with long-term accident data to obtain more accurate scenarios of road traffic accidents and casualties as well as their trends. Traffic district level accident data can be used in future for analyzing spatial variations in accidents in more detail. Other related information like road network, population, landuse, topography, etc.

can be considered to understand influential factors responsible for spatial and temporal variations in road accident.

Acknowledgement

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