Ambulance Emergency Responses Vulnerability Analysis Towards Traffic Conditions using GIS

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ABSTRACT

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Rising incidents of emergency responses late arrival at the crime scenes due to the issue of increasing traffic volumes day by day has becoming one of the concerns in KL City Centre. The traffic congestion could hinder emergency responses that need to reach the accident location within stipulated time. The purpose of this study is to analyse the vulnerability of ambulance emergency responses towards traffic conditions using GIS. In this study, the Ambulance Responses Traffic Vulnerability (ARTV) Index is introduced to measure the variability in ambulance responses performance due to traffic vulnerability in each region since KL City Centre is an urban area where traffic-congested happened every day. The ARTV index is unitless, and a higher ARTV indicates that the area is more vulnerable to traffic conditions and travel time uncertainty, whereas a lower ARTV indicates that the area is less vulnerable to traffic conditions and travel time uncertainty. By computing the value of this ARTV Index, it is possible to determine which locations are least vulnerable, intermediately vulnerable, vulnerable, and most sensitive to traffic conditions, particularly during peak and off-peak hours. Based on the finding, the central part of KL City Centre has high ARTV index indicating the ambulance responses tend to be vulnerable towards the traffic condition, thus the responses time may be slower when the traffic congestion is high. The ARTV index was visualized as a map which is expected to be useful as a guidance in improving the emergency responses in KL City Centre.

Keywords: *traffic congestion, emergency response, ambulance, GIS*

INTRODUCTION

Traffic congestion is one of the most challenging issues to be solved by any government. It has become one of the key concerns that need urgent consideration. However, to solve it by constructing additional roads, might be financially and environmentally infeasible, thus, is not the optimal solution for congestion (Debashis, 2019). Many facilities depend so much on the quality of road networks so they can maintain the quality of their access to their demand. Healthcare services is one of those facilities as they aim to provide service to the community that require it. Healthcare facilities such as clinics, hospitals, outpatient centres and advanced care centres are very important as people need them every day. Their services such as ambulance plays a major role when a road accident occurs and there is a need to save valuable human life. Transporting a patient to a hospital seems to be easy, but it can be complicated especially during peak hours due to traffic congestion, especially in metropolitan city (Shashikala, 2020).

Kuala Lumpur is a metropolitan city that is well-known for its heavy traffic every day. This is because it is the heart of the country where people travel to their workplaces and for other businesses. However, the traffic congestion might influence the emergency responses. Precisely, road congestion could increase the emergency responses time for rescue services (Roopashree, 2020). It had been stated that the number of deaths due to delays in the delivery

of emergency vehicles has risen to a larger degree in recent years (Paul, 2014). Owing to the rise in population and the increasing usage of cars, it has become a significant obstacle for emergency services, such as ambulances, to travel around in emergencies (Suman et al., 2020). Emergency services such as ambulance and fire truck need to arrive on time to avoid loss of human life (Saido, 2012). In most developed countries, smart and adaptable traffic control systems are currently favoured over fixed-time systems. In the present traffic condition, it is very necessary to assist an emergency vehicle to travel regardless of traffic conditions. Emergency service providers need to respond to an emergency in the shortest amount of time possible. However, traffic congestion can be a huge reason that impacts the travel time of emergency services.

For medical emergency services, they should respond to Emergency Medical Services (EMS) calls within fix timeline which varies based on the policy of each country, but most countries stated that it should be within 8 minutes. The response time is very important for the ambulance to arrive early at the location with critical emergencies. South Korea set the travel time target as 5 minutes or less with 74% of an emergency call by 2017 (Jung Yoon et al. 2015) while in England, their national standard for the response time is 8 minutes or less in 75% of threatening cases. However, in Malaysia, the timeline for responding to EMS calls is within 15 minutes which is 7 minutes longer than practised in developed countries. This might be due to the traffic congestion in the country. Therefore, something must be done about this. Perhaps in real-time, alerting the ambulance in advance to take other routes instead of the congested ones. Road planning has always been one of the most important parts of transportation and logistics. Many techniques had been introduced to aid in road planning including GIS. Thus, this research aimed to use GIS application and its extension to analyse the vulnerability of emergency responses in different traffic conditions. GIS is a system that supported by computer for capturing, querying, storing, analysing and displaying the geospatial data. It has immense potential to benefit the healthcare industry. GIS also is very well-known to be a useful tool in planning a road network in a new area. Gopala Raju et al. (2012) have studied the road network in Visakhapatnam city using GIS. In this research also, each referral hospital service area is determined by the accessibility of the hospital within a certain time by using catchment area analysis. The analysis will show roads that can be reached within a given distance or drive time. It is often used to show the emergency response coverage such as for ambulance and fire truck.

This study will attempt to use GIS to measure the vulnerability of ambulance coverage due to traffic condition by comparing the variability of coverage among different areas or district. The road network data used in this study is a secondary data that has been taken from the Esri and TomTom websites. Road network data has information such as travel time of each road. Higher index means that the area is having high vulnerability of traffic condition. Based on the vulnerability analysis, the impact of traffic condition to emergency responses will be analysed based on the shortest path analysis for the ambulance to reach accident location using time as impendence. The aim of this study is to analyse the vulnerability of ambulance emergency responses towards traffic conditions by using GIS while the objectives of this study are (i) to identify traffic conditions in KL City Centre for different hours in a day, (ii) to determine the time taken of ambulance for responding to emergency case in KL City Centre in different traffic conditions, and (iii) to analyse the impact of traffic conditions towards emergency responses.

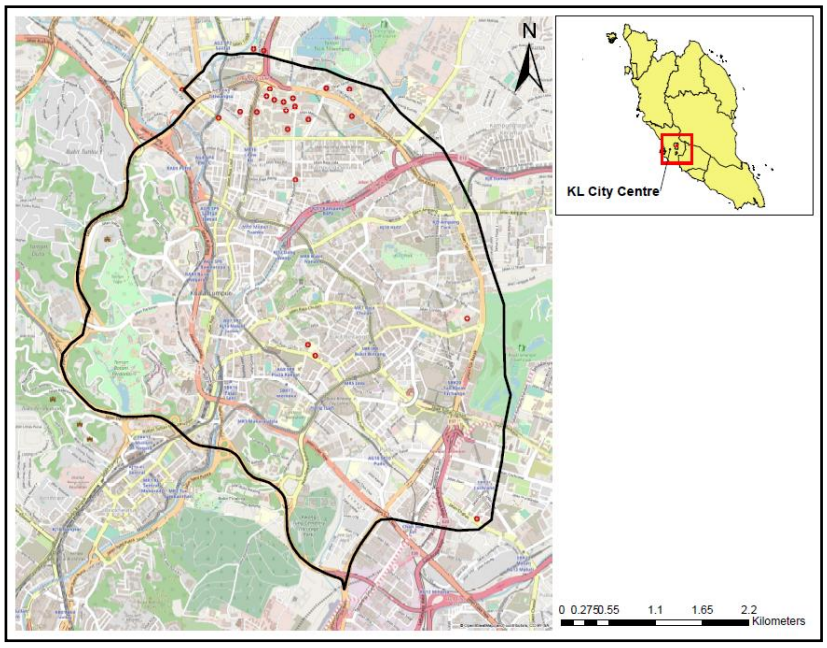

Figure 1: Area of KL City Centre

KL City Centre was chosen as the study area due to the traffic congestion the city experiencing till date as shown in Fig. 1. Based on the Traffic Index 2020 which was released by TomTom, who is a a global road traffic data provider, Kuala Lumpur ranked 77 among 416 cities across the globe, 4th among South East Asian cities behind Bangkok and above Singapore. The ranking was meant to rank the traffic congestion in urban area worldwide. This fact could affect the ambulance emergency responses as many studies suggested. It is also one of the fastest-growing metropolitan areas in Southeast Asia, both in terms of population and economic growth.

LITERATURE REVIEW

Traffic Flow in KL City Centre

Traffic congestion on the roads is primarily the product of overcrowding. The phenomenon occurs when a large number of vehicles enter the lane, resulting the disruption of the orderly flow of traffic. This has a huge influence and disrupts on people's everyday lives. The time spent on the roads has a number of detrimental impacts on efficiency, social behaviour, environmental and economic costs. Besides that, congestion worsens and creates mayhem during crises such as flooding, fires, road repairs, and so on where the traffic flow activity is often erratic and uncontrollable. It has been observed that congestion exist on every major road in Kuala Lumpur and much of it is due to offices and economic also commercial centres during rush hours (Ali et al., 2018).

The traffic condition in Kuala Lumpur Malaysia is still very severe, particularly during rush hours in the morning when people leave for work, go to school, and other daily activities, during lunchtime, in the afternoon when people return home. The congestion of traffic congestion usually happening within the hour of peak hours such as from 6.30 a.m. to 9.30 a.m. which is where the group embarks on activities such as going to work, school and so forth. Then, from 4.30 p.m. to 10.00 p.m., it is the time for the community to return from work or other activities done throughout the day. Besides the heavy traffic condition also happened

during lunch hour, is because at that time is the lunchtime for all workers and workers usually go out for lunch by the time 12.00 p.m. (Reshadat et al., 2019).

In the theory of urban development, it is often clarified that the development of a city is affected by the geographical circumstances of the city and its transport routes. Cheap roads, railroads and canals may be made in flat areas such that some land uses, for example, are extensively extended by the industry. Furthermore, in general, big cities such as KL City Centre have the same experience in the transport market including traffic delays on the highway. Increasing the population would promote an increase in the demand for land (Hermon, 2017). The increase in population in Greater KL will also result in an increase in the number of vehicles in urban areas and that will be causing highway and traffic problems, particularly on major roads.

In addition, the traffic congestion that exists in KL City Centre is more serious than Kajang or Putrajaya is because KL is the hub of various events and activities. Traffic congestions also occur in all downtown areas as well as in tourism areas and the uniqueness plus the diversity of nature make it very desirable to increase the number of visitors visit to the city.

Factors and Impact of Traffic Conditions on Emergency Medical Services' Responses

Traffic congestion is a global and critical issue due to increased demand and the restricted structure of the transport network. There are reasons why traffic congestion in the Greater KL is still becoming a big issue nowadays. The complex traffic structure, imbalance traffic flow and uncertain events like road accidents are among the identified factors that may cause traffic congestion (Abdelfatah et al., 2015). Another factor of why traffic congestion happened especially in urban areas such as Greater KL is the rise of numbers of private vehicles. People in Malaysia, especially in urban areas like the Greater KL area they tend to use private cars so they can travel straight to their destination. There was a study revealed that they are reluctant to use public transportation such as buses and trains because when they need to make interchanges between different transit services to reach their final destination. The reason for using private cars while going to work and other events is typically because they want to save time and public transport is usually slower (Hasmita & Radzuan, 2018).

The population growth not only raises demand for employment openings and demand for accommodation but also increase the number of cars on the highways and roads along with social facilities. This situation is in line with the statement said above the rising number of vehicles and the growing population resulting in a rise in traffic congestion in Greater KL earlier. As the car price in Malaysia is relatively cheap, many people can afford to buy it. However, as more people own a car, more people will use it as their medium of transportation, thus leading to the increasing number of cars on road. This will then cause traffic congestion.

Generally, EMS relies on the vulnerability of traffic conditions in an area or a patient's location. Traffic congestion has a big impact on EMS response time to reach the location. This is because, the ambulance should arrive on time to save one's life due to its injuries however, the arrival delay has made many patients who met severe accidents is affect them badly. The patient may never survive when they did not receive first aid treatment. Any of the patients still did not survive because the ambulances could not get to the hospital as fast as possible due to traffic congestion (Nasir et al., 2015). The urban population is growing as a result of migration from rural areas and since transport mode are also increasing in urban areas which create traffic

congestion, in the event of an emergency traffic blockage, response time is sometimes be slowed down for ambulance to reach patient.

The unplanned and congested road network disrupted the rescue mission leading to an abnormal death sentence (Technica, 2016). Traffic congestion also will interrupt the victim's first aid system and adversely impact the time of arrival and reaction at the scene. Some drivers also did not hear and notice the emergency alarms which made it more difficult for the EMS to get to the scene. In addition, not all services such as police officers, firefighter including EMS were deployed at the same time (Safi Keykaleh & Sohrabizadeh, 2019). Any people neglected emergency sirens, led to heavy traffic near the scene and congested the site of the crash.

The 'Golden Hour' trauma theory acknowledges the time-sensitive aspects of trauma and indicates that the mortality and morbidity of trauma victims may be impaired if definitive treatment is not taken within the first hour of injury EMS is included in this debate as they are responsible for delivering acute pre-hospital treatment for patients with disease and disabilities and play a vital role in providing quality healthcare to individuals, reducing the degree of injury also the death toll however due to road density in many urban areas of the country, traffic congestion causes extreme car congestion and thus response time for an ambulance (Cabral et al., 2018).

Longer EMS response times due to heavy traffic condition also have been associated with the worst outcomes in trauma patients. In Bangladesh, for instance, the most recent incident took place in the year 2013 when a nine-storey Rana Plaza building collapsed in Savar killing 1127 people and more than 100 people are still missing. The late arrival of EMS ambulances due to traffic congestion in the city has made many people died before being treated. Other studies also have noted that due to the lack absence of a pre-hospital EMS due to traffic congestion, many patients arrive too late and those with severe injuries may die before providing the emergency care they require while others die instantly upon arrival in an accident and emergency hospital due to inadequate emergency care rendered before their arrival (Yau et al., 2016).

GIS in Analysing Impact of Traffic Congestion

Geographic Information System (GIS) provides an extremely versatile and useful means of testing the implications of demand scenarios and standard for this service delivery factors and thereby contributes to better-informed decision-making. GIS Visual and Text equipment allow the user to see the effects of the study before and after each change. In addition, it is possible to see attainable outcomes in the GIS analysis by modifying input data or other parameters. Using GIS and traffic parameters are integrated to determine the location of emergency services along with the road network in an area as one of the most important and powerful functions in GIS is the network analyst (Pour & Moridpour, 2015). The network analysis provides network-based analysis such as travel direction, nearest facilities, and location distribution or in other word is location-allocation.

The applications of GIS technology in public health had been widely recognized for its success though there are still some challenges in it (Eastwood et al., 2016). GIS can be used to identify the EMS location by using that network analysis. In the analysis, the service area for each EMS location is determined according to the travel time volume for each segment of the road. The service area then is analysed by network analysis tools in the GIS Arc tools. Meanwhile, the density for each segment of road is determined by using the density analysis

in GIS. The EMS coverage area is measured using a simple set of travel distance and speed assumptions such as Euclidean distance and speed limit (Cho et al., 2017).

To identify the position of emergency services, the most important criteria are the arrival time. This can be solved by using GIS to calculate the travel time cost (Pour & Moridpour, 2015). Apart from using network analysis to identify the EMS location, it can also be used to find the shortest path for emergency services to reach the patient due to delayed response time to reach the patient caused by traffic congestion. Application of GIS to measure the spatial accessibility to primary healthcare facilities in a country and to apply a driving-time analysis to determine the shortest time between each population and healthcare location across road network (Murad, 2018). Once the speed profiles have been imposed on GIS, the shortest time of travel route from EMS location can be calculated. The efficiency of EMS service ability can be measured by the percentage's reduction of coverage relative to the baseline case of the speed limit.

The present research has used the allocation and service areas function that available within GIS Network Analysis to access the functionality of healthcare services. This function can find the accessible streets within a certain distance of the location and thus the streets that are not selected by this function are represented as problem areas. GIS also used to do analysing the impact of traffic congestion towards EMS responses to find out the most vulnerable traffic condition in an area that causes traffic congestion by using index analysis. The index analysis uses traffic volume data to perform and shows the result of traffic vulnerability in the area into three categories which is low, medium, heavy. Conducting vulnerability studies using GIS is a relatively recent field of study but the capacity for GIS to highlights spatial problems in this area is becoming evident (Nicora & Haidu, 2015).

The usage of GIS in analysing impact of traffic towards EMS has proven to be a valuable method to track respond, control and minimise the impact of disastrous incidents and is successfully used for various phases of disaster management, beginning with preparation and risk assessment (Church & Cova 2005). Geocode the current land use ad road network of the research areas and then establish an optimal path model to be used for network analysis and map the successful coverage areas of existing emergency medical services responses such as hospitals also can be achieved. Thus, it can be concluded that GIS can be used by hospitals to produce and effective and efficient emergency responses during a disastrous situation in heavily populated urban areas where traffic congestion happened (Technica, 2016).

METHODOLOGY

This section will be explained detailed procedures or techniques used to complete a research project. Besides, this chapter also will discuss on the methods that have been used in the collection and analysis of data involved to attain the objectives of this research. All the stages involve in the methodology of this research is illustrated in Figure 2.

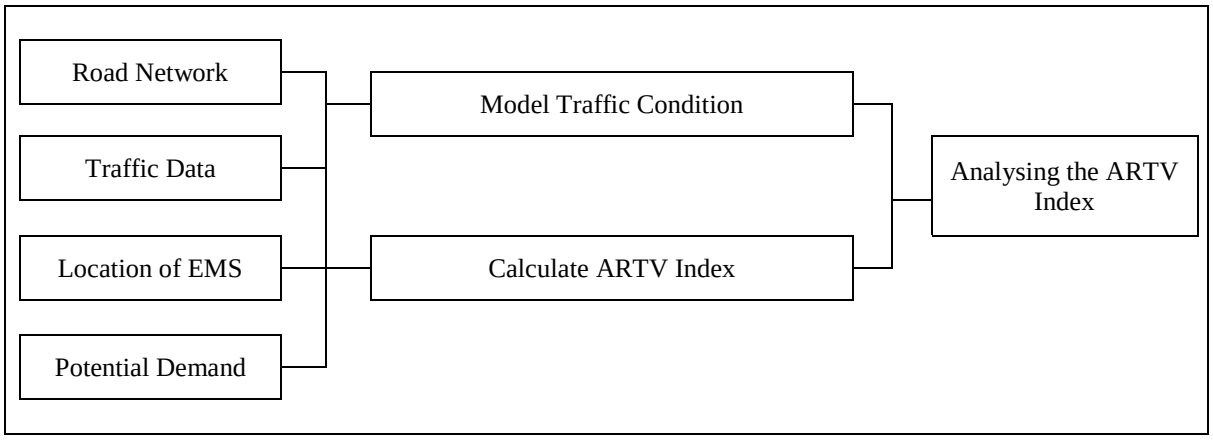

Figure 2: Methodology

The road network data included in this study is all roads in KL City Centre area including the primary, secondary and tertiary roads. The traffic data for this study had been downloaded from the TomTom Move website where it provided information about the traffic flow at KL City Centre. The data also provided about how travel speed on specific roads segment is changed over time. It is important in network analysis because traffic condition affects the travel time of ambulance to reach demand point. For this study purpose, the data is dated April 2019 34 and was downloaded for every hour and 7-days of the week. A report is generated and the data is attached in an appendix A. The report details had shown time for every hour for each day which is from Monday to Sunday, and it was given in a text format. In this study, live traffic data was used to seeing the variations of traffic volume and well work together with road network dataset to modelling the traffic condition to see how traffic condition influence the Emergency Medical Services (EMS) responses from hospital to demand. The data also has shown traffic flow on KL City Centre with a different colour range that indicates slow, moderate and heavy traffic condition.

The location of EMS in the study area were collected from Google map and each EMS station was geo-located on ArcGIS 10.6. The data then had shown the distance from the hospital to the demand point and were represented as a point feature. For this research study, the location EMS collected are both government and private. The total number of EMS location collected were ten (10) including the Tung Shin Hospital, Prince Court Medical Centre, Kampung Baru Medical Centre, KPJ Sentosa Kuala Lumpur Specialist Hospital, Kuala Lumpur Hospital, Institute Jantung Negara (IJN), Malaysian Red Crescent Society (MRCS), Pusrawi Hospital, KPJ Tawakkal Kuala Lumpur Specialist Hospital and Sunway Medical Centre.

In this study, the potential demand of accident was represented in point by using the land parcel in KL City Centre obtained from Kuala Lumpur City Hall. The data received were in raster type which is the imagery with the size of A1. The land parcels were digitized first to generate the polygon dataset for the land parcel. The polygons were then converted to point features representing the potential demand to indicate potential location of accidents. This is because, in real life situation, accidents can happen anywhere within the KL City Centre area and not only concentrated in one place. Thus, land parcel with various type of land uses such as Residential, Institution and Trading has been used as potential demand to represent the accident location.

It is often beneficial for any data to have less measure of uncertainty. A smaller or larger value for variability means that the values are more or less constant based on the average. There is a need for a relative measure of variability for a fair comparison that is free from the fact that the averages might be different. Therefore, in this study, the planning was to find the vulnerability of emergency medical services (EMS) which is ambulances coverage due to traffic conditions by comparing the variability coverage between different regions in KL City Centre as the area is an urbanization area. In this study, the Ambulance Responses Traffic-Vulnerability Index (ARTV) is introduced to measure the variability in ambulance responses performance due to traffic vulnerability in each region. The index metric was calculated using Equation 1.

$$\text{ARTV (x)} = \frac{\text{range of x}}{\text{mean of x}} \quad (1)$$

Based on the metric used to the range of values was divided by the mean value as the measure of variability, this measure also provides a useful estimate for qualitative analyses. Instead of using 15 minutes directly where ambulance should have arrived at the accident location, a new algorithm has been created for this study purpose as the x in the range is the total travel time from hospital to demand of every hour and x in the mean is the distance from hospital to reach each demand. The ARTV is a unit less also can draw implications that some regions are more vulnerable than others. To put in simple words, a district with an ARTV index value that close to zero (0) means that there is little effect of time-of-day and day-of-week while a district that has an index value far from zero (0) means the opposite. Because of that, there is a need to compare the values among districts and performing the ARTV, which will provide such a comparison. This analysis also is used to identify which time ambulance affected by the traffic condition every hour as the index result will result on every hour and show different area received the Emergency Medical Services.

Table 1: Classification of ARTV Index

Classes	ARTV Index	Description	Symbology
1	<0.25	Least vulnerable	
2	0.25 – 0.50	Intermediate	
3	0.50 – 0.75	Vulnerable	
4	>0.75	Most vulnerable	

As explained previously, the High ARTV Index (value far from 0) indicates high vulnerability of the emergency responses towards traffic condition and vice versa. Therefore, the symbolisation used visual variable “Value” with the shade from green to red with green being the least vulnerable (Low ARTV Index) while red being the area with the most vulnerable (High ARTV Index) as shown in Table 1. Thus, the area with red shades shows that they are the most vulnerable to traffic condition and having a value far from 0. On the other hand, the area with green shades is the least vulnerable to traffic condition as they are having a smaller ARTV index or having a value that is close to 0.

RESULTS AND DISCUSSION

In this study, the ARTV Index is introduced to measure the variability in ambulance responses performance due to traffic vulnerability in each region since KL City Centre is an urban area where traffic-congested happened every day. The index metric was calculated using Equation 1 discussed in Section 3.

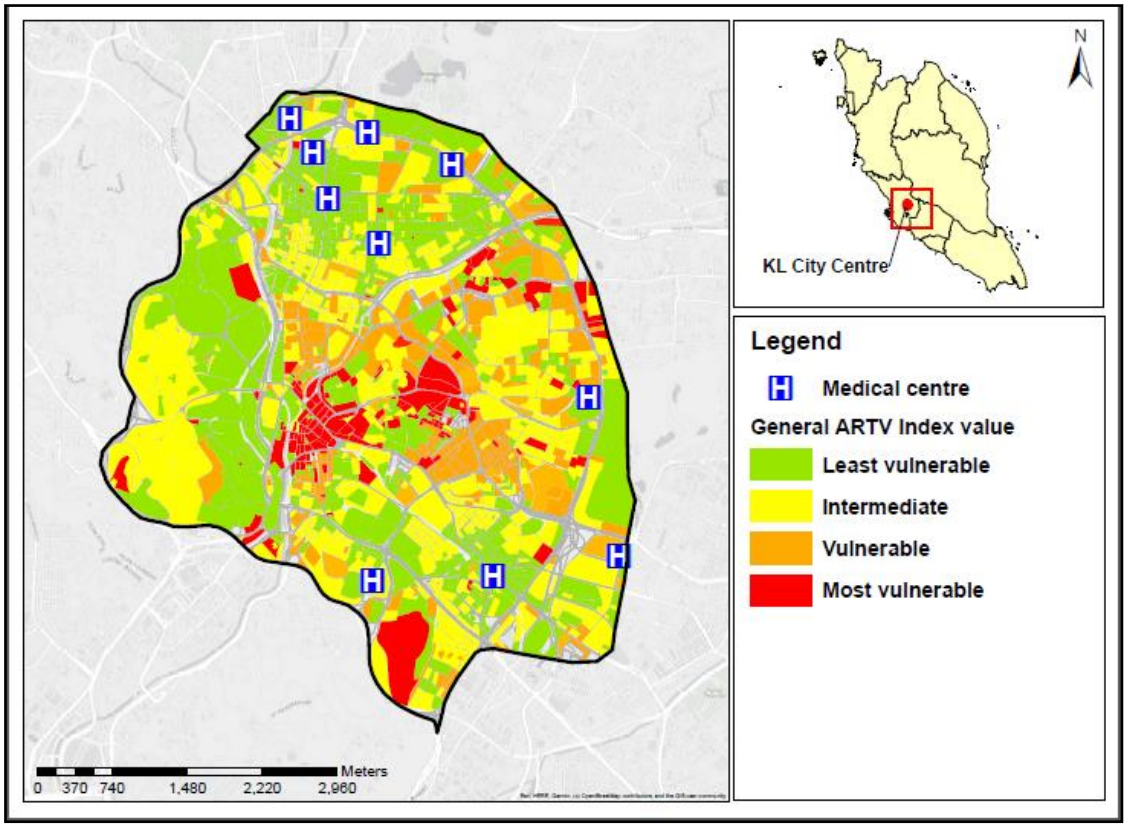

Figure 3: ARTV Index in KL City Centre

In general, most areas are least vulnerable to traffic condition. However, there is a certain area which on peak hour, are vulnerable to traffic condition. Besides, the result has shown some areas constantly received poor EMS every hour. This is due to the traffic-congested in the area on peak hour together with low accessibility for an ambulance to reach the areas as the areas located in a remote area. There are also changes in the index throughout the days in certain areas and there are stays the same.

Based on the ARTV Index, it can be seen that in the study area, the same area has a high ARTV Index per hour, namely around Kuching Road and Ampang Road. One of the areas with a high ARTV Index was at Taman Tugu Negara, Taman Botani Perdana, Masjid Jamek and some areas in Gombak where the secondary road is linked with main road Kuching Road, Sultan Salahuddin Road, and Parliament Road as well, but the main road used for these areas to reach is Kuching Road. In Kuala Lumpur, Kuching Road is a major thoroughfare. It is a part of Federal Route 1, an old trunk road that links major towns on Peninsular Malaysia's west coast. Kuching Road in Kuala Lumpur starts from Jalan Kinabalu in the south to the Kepong Roundabout where it becomes Jalan Ipoh. This is the reasons why the traffic at Kuching Road is usually congested during morning and evening due to many people from different areas including people from Rawang used the road to reach their offices in the city centre.

Meanwhile, Ampang Road is also famous for its always congested traffic. Ampang Road is also one of the main roads of KL, so it is no wonder that it is one of the worst traffic-congested roads in KL especially in the morning and evening. Besides, Ampang Road is a long road and there are quite a several shopping malls and hotels along the way towards the city centre. One of the famous landmarks is KLCC Twin Towers thus the surrounding areas were always filled with people as well as foreigners. Other than that, the traffic jam that often occurs in this area has made it difficult for ambulances to reach the scene of the accident on time as the colour represents Ambulance Responses Traffic-Vulnerability Index based on the traffic condition and its speed. The colour then was classified into four ranges of red hue colour which from least vulnerable to most vulnerable to the traffic conditions.

Area with a low ARTV Index means that it is less affected by the traffic conditions. This means that the ambulance responses are less vulnerable at that time, thus they might reach the accidents' location faster than an area with a high ARTV Index. Thus, the ambulance can reach the scene in a short time as well as potentially rescue the victims if they suffer severe injuries hence no deaths occur. It is found that the area with a low ARTV Index value per hour is around the area of Pahang Road, Hang Tuah Road, Pudu Road and Ampang Road. One of the areas with a low ARTV index was Kampung Baru, Kampung Pandan, Ampang and some areas in the north-eastern area of KL where the road is connected to Pasar Road in Pudu and the main road, Sultan Ismail Road.

Besides, areas with low ARTV Index were concentrated in areas close to the hospital and are least vulnerable because they have index values close to 0. Furthermore, the size of areas with low ARTV Index changes from time to time. This is due to the traffic conditions at that time and the ARTV Index for this area is also low based on the traffic condition at that time. In other words, an area with low ARTV Index changes on both peak and off-peak hours.

CONCLUSION

The increasing number of vehicles on the road has led KL City Centre to face the increasing number traffic volume day by day currently. The traffic situation in Kuala Lumpur Malaysia is still pretty bad, particularly during rush hours, such as in the morning when people go for work, school, and other activities, during the day during lunchtime, and in the afternoon when people return home. EMS could have a significant impact on whether or not a patient survives due to late arrival at the scene which leads to the second objective which is to determine the time taken of an ambulance to respond to an emergency in KL City Centre in various traffic conditions. For this purpose, an index namely Ambulance Responses Traffic-Vulnerability (ARTV) Index has been introduced to overcome the problem. The study has revealed that areas with a high ARTV Index are more frequent in the central part of KL City Centre and some at the southern. The ARTV was visualized in a static map to show which the vulnerability of EMS towards traffic condition on different hours for different parts of the study area.

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AUTHOR CONTRIBUTIONS & CONFLICT OF INTEREST

The authors' contributions are as follows:

Nur Amirah Suhaimi	:	Review of literature, Data Collection, Data Processing, Data Analysis, Visualization
Nabilah Naharudin	:	Background study, Designing Methodology, Data Analysis

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