Feasibility Study on Walkable City Through Implementation of Car-Free Zones and its Effect on Traffic Movement in Georgetown, Penang Using GIS Network Analysis

Abdul Hakim Salleh¹, Nabilah Naharudin*², Maisarah Abdul Halim², Nurfadhilah Ruslan²

¹School of Civil Engineering, Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Pulau Pinang, Malaysia
²Centre of Studies for Surveying Science and Geomatics, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

nabilahnaharudin1290@uitm.edu.my

Abstract. For many years of vehicle technology developments, people have a tendency to not be separated from it. Excessive reliance on vehicle especially personal cars causes large span of available spaces were dominated by it. This situation has led to many significant issues in both urban and rural area which include congestion, safety on the road, and environmental sustainability issues. In order to cater these degrading issues, the car free and walkable city concept was applied in this study. Through these concept, sequential reduction in the number of cars on the roads and shifting of people’s mode of transportation would be possible. The principle of walkability together with limitations of vehicle accessibility area as the criteria in car-free spatial modelling is applied and presented in terms of maps showing the areas to be designed as car-free zone. The percentage of Georgetown's pedestrianized streets is determined in conjunction with an evaluation of the impact of car-free zones on the route, distance and time of travel, and also its traffic impact projections around the area. It is found from the results that every localized traffic has a longer traveling distance and much slower pace. However, the travel time is sometimes reduced due to the roads that have been diverted to allow for a higher travel speed.

1. Introduction

The concept of walkability has often been linked to a city's urban planning area in which it can be determined in several aspects, such as environmental characteristics, transforming a city into a safe and compact environment, improving potential environments, making the city more liveable, and being the holistic solution to any urban problem as stated by Forsyth (2015) in [1]. Penang is facing enormous development pressure because of the tourism development activities, as experts claimed that local culture and heritage were exploited by increasing economic demands from the intensively growing tourism industry as stated in Lim (2011) in [2]. Car-free environments potentially reduce the traffic hazards that motor vehicles pose to pedestrians by prohibiting motor vehicle traffic altogether (except for commercial deliveries early in the morning), except on cross-streets with motor vehicle traffic. [3].
Thus, will increase the tendencies of having worse congestions, and increase in accidents whether vehicle to vehicle, or vehicle to pedestrians. Imposing stricter rules or installing more infrastructures in order to control the traffic movement will only produce a short-term result as more people will feel encouraged in using the infrastructures as stated by Buis (2009) in [4]. To reduce or eliminate the problem in total can only be achieve by limiting the vehicles to go through the concerned area by introducing a walkable city. For the established association, there are several potential mechanisms and they come from the advantages of pedestrianization, which refers to preventing motor vehicles from accessing a determined area, as stated by Soni (2016) in [5]. A walkable area means the priority of travelling is focused for pedestrians rather than motorized vehicles [1]. The pedestrian-oriented cities can reduce if not eliminate the domination of motorized vehicles together with its bad impact such as their hazards of accident, and pollutions such as air and noise pollution as stated in Safety ITF (2012) in [6]. To further increase the walkability and reduce car dependence, some cities plan to go “partly” car-free such as Hamburg and Madrid [7]. This study intended to propose a car-free zones in Georgetown, Penang and touch on its impact towards traffic movement. The car-free zones is simply a controlled zone which does not allow private vehicles to enter or at least highly discouraged, and with this rule, the area of which private vehicles can drive is limited to the major roads [8]. With UNESCO heritage status in Georgetown, small roads and being one of a touring destinations area in Penang, car-free environment will increase its sustainability especially in terms of walkability. This study comprises of determining the suitable area for the car-free zone and the impact of the vehicle’s movement in the proposed area. The quantitative spatial analysis will be conducted through GIS in modelling the car-free zones based on the available tourism point of interest, which is mapped based on walkability that covers the street connectivity, diversion of vehicle's path and traffic density.

2. Methodology

The study begins with the identification of suitable area for the car-free zone. This process requires several step of GIS data preparations. Firstly, is the georeferencing of the basemap based on the several point of known coordinates, followed by the digitization of locations of tourism points of interest which includes under UNESCO heritage area and road networks throughout Georgetown. Secondly is the preparation of traffic and network datasets with attributes as shown in Figure 1 which respectively, consist of 119 individual traffic maps and network attributes such as segmental distance, road classes, speed, lane, directions, one- or two-ways information and time. Finally, is the spatial and network analysis. As for the coordinate system, the whole datasets were projected in World Geodetic System 1984 (WGS84) - Universal Transverse Mercator (UTM) 48 North, which is the projected coordinate system for Peninsular of Malaysia.

![Figure 1. Attribute table of road network](image)

The digitized point of interest was registered into single categories although it comprises of historical sites or buildings, arts such as street mural, modern attraction such as 3D museum and shopping mall as shown in Figure 2. The early spatial analysis was Kernal density which analyse the hot spot of point of
interest throughout the Georgetown. The tourism spot was determined based on direct observation of the result map together with the availability of nearby main road as the boundary of the car free zone.

As of early stage of research, the study was conducted as pilot where the data were all obtained through an open-source data provider. Thus, the traffic data were obtained through Google Map traffic service provider. Google provides the data with interval of 5 minutes update and it were represented in colour updates. Green being the low traffic until the dark red to be the total halt. Due to various factors, such as the number of GPS samples used to estimate the speed in a given road segment and their respective accuracy, traffic regime, etc., the crowdsourced traffic speeds obtained by aggregating GPS information from different sources (e.g., Google Maps users in the case of Google traffic data) can vary significantly between consecutive time intervals. The same applies to other popular providers of commercial traffic data, such as INRIX or HERE, which rely on GPS data from different sources, ranging from mobile phone users to contract fleets (e.g. delivery vehicles and taxis) [9].

As for this study, hourly updated maps between 6am until 10pm were captured for 7 different days and each map were georeferenced precisely. In total, there were 119 traffic maps. All maps were supervised classifications based on the colour codes as well as the other features such as green area and water bodies. All maps were then reclassified into 6 classes of weightage started with blank area which represent the least traffic, green to be low in traffic, light brown for fair amount, red as heavy and dark red as very heavy in traffic while other than the traffic data was set to blue colour which later were removed as input data. These information were then overlayed with over 2000 points along the road network with maximum interval of 100 meters from one to another based on its road segment as shown in Figure 3. This is to capture every bit of traffic condition throughout the study area.

The resultant maps are the vector point maps with an attribute of more than 2000 points describing the classes of traffic for 119 hourly maps. The early analysis was made through the identification of three daily peak hours. The result is three group of maps of three hours. First is from 7am to 9am, secondly is from 11am until 1pm, lastly is from 4pm until 6pm. These maps were then averaged through Raster Calculator tool which results in just 3 maps per day. The process was repeated with the closure of roads in the car free zones region. Figure 4 shows a map on Friday with the traffic data before the closure of road in the blocks. The road network inside the block were then removed and the traffic data point inside it were moved to the neighbouring roads representing the increase in the number of vehicles as shown in Figure 5.
Figure 3. Traffic data based on Google Map

Figure 4. Example of mean traffic on Friday from 4pm to 6pm before closure of road for car free zone (with internal roads)

Figure 5. Example of mean traffic on Friday from 4pm to 6pm after closure of road for car free zone (without internal roads)
As for the road network, the process of digitizing was made together with the registration of its attributes such as road speed limit and distance which were used to calculate the time factors. Apart from that is the determination of directions of road and its characteristics such as one way or two ways, which is very important in having high accuracy rerouting process. The final of the digitizing process is the topological check in which no dangles rules were applied. The last process of the road network is to convert it into a network dataset which brings the bunch of digitized lines into a functional road with impedance factors.

3. Results and Discussion
The density map of tourist attractions places was used to determine the potential of developing as a car free zone. The map was symbolized into several levels in order to have better visualization for the observation process. The most attractive places are concentrated in the UNESCO core zone. This place is indeed among the most well-known and popular area for tourist that visits Penang. The area was enough for pedestrian to walk from one end to another. It was not too vast nor too small. Therefore, the development to increase the level of comfort of the pedestrians is easily to be made. Moreover, with the main roads were on all sides, this made the area is highly suitable as it will sustain the movement of the vehicles surrounding the area.

![Figure 6. Kernal Density of tourism point of interest.](image)

In this study, the selection of streets for car-free zones is done in groups but not individually, which turns them into zones. Every proposed car-free zone in this study has a street network rather than just a single street. This is in line with the car free zone model which a number of roads, though may not in the true grid, is in the zone. Furthermore, the main traffic roads around the proposed car-free zones form blocks on them, the same as the car free zone model, which has basic roads around it. They both provide alternative ways to channel the traffic bypassing them. Inside the car-free zones, all roads are closed for traffic to pass through the area. Therefore, this situation gives the car-free zones the same exterior and interior components as the car free zone. It was found that after the rerouting of vehicles for car-free zones, the most affected days was Friday and Saturday in the late afternoon where the traffic diverted increases tremendously as shown in Figure 7.
Before road closure for car-free zones

During road closure for car-free zones

Friday 4pm to 6pm

Saturday 4pm to 6pm

Figure 7. Traffic condition before and after the road closure for Car-Free Zone.

In the comparison of travelling routes, through direct observation, all routes show an increase in travelling length to bypass the car-free zones, as the traffic must travel around the zones to reach the other side compared to the situation before in which a more direct route that passes through the area can be taken. This can be proved by the results of the increase in travelling distance in Table 1. Though every rerouted traffic shows an increase in travelling distance, their travelling time, however, does not increase, sometimes even under a longer travelling distance. This is because the roads that have been rerouted have a higher design speed limit, which allows traffic to travel faster. The results of the change in travelling time are shown in Table 2.

| Route | Before (m) | After (m) | Distance increased (m) | Percentage increased (%) |
|-------|------------|-----------|------------------------|-------------------------|
| 1     | 622.663    | 954.37    | 331.707                | 53.27                   |
| 2     | 541.725    | 981.358   | 439.633                | 81.15                   |
| 3     | 592.286    | 1014.72   | 422.334                | 71.29                   |
| 4     | 568.93     | 642.22    | 73.29                  | 12.88                   |
| 5     | 263.456    | 447.147   | 183.691                | 69.72                   |
| 6     | 317.697    | 576.021   | 258.324                | 81.31                   |
| 7     | 561.526    | 1543.767  | 982.241                | 174.92                  |

Table 1. The extracted results of the change in travelling distance.
Table 2. The extracted results of the change in travelling time.

| Route | Before (s) | After (s) | Time increased (s) | Percentage increased (%) |
|-------|------------|-----------|-------------------|--------------------------|
| 1     | 93.55      | 87.01     | -6.54             | -6.99                    |
| 2     | 77.02      | 98.39     | 21.37             | 27.75                    |
| 3     | 103.73     | 117.33    | 13.6              | 13.11                    |
| 4     | 93.28      | 70.77     | -22.51            | -24.13                   |
| 5     | 31.31      | 40.77     | 9.46              | 30.21                    |
| 6     | 35.42      | 49.18     | 13.76             | 38.85                    |
| 7     | 70.40      | 154.46    | 84.06             | 119.40                   |

4. Conclusion
This study presents the implementation of potential car-free zones using spatial analysis, aiming to increase the walkability and promote the walkable city in Georgetown UNESCO core zone, Penang. Through this study, it is found that the creation of car-free zones in a city that is dominated by cars is feasible using GIS. GIS helps to visualize and classify the city into zones spatially according to the criteria that required. It can also spatially combine and overlay every map produced from each criterion, which helps and eases the work of modelling and analysis. Therefore, by implementing suitable techniques to perform analysis, car-free zoning can be realized through spatially referenced information and visualization.

All procedures of processing and analysis have fulfilled the objectives of this study. In conclusion, this research has quantitatively and spatially identified the locations where they are the most suitable for the establishment of car-free zones. This study has effectively generated classified maps based on the required criteria to allow the proposal and modelling of car-free zones. Besides, it has also identified the effect on traffic from the aspects of travelling route, distance, and time. In short, with the aid of GIS, incorporated by the traffic and transportation analysis, the research on quantitative modelling of car-free zones can be conducted fruitfully and feasibly.

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