ASSESSMENT OF THE CAR-FREE DAY IMPLEMENTATION ON UTM CAMPUS USING A SHORTEST PATH METHOD

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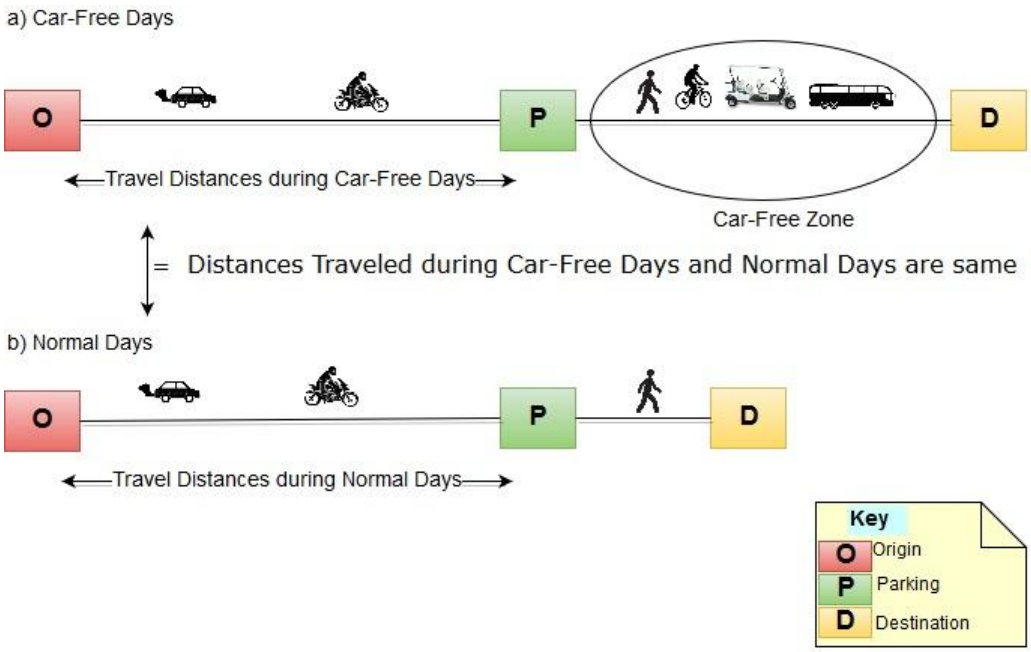
GRAPHICAL ABSTRACT



ABSTRACT

Car-Free Days (CFDs) were introduced on the Universiti Teknologi Malaysia (UTM) campus and intended to reduce vehicle emissions, promote healthy lifestyle modes of transportation and improve environmental sustainability awareness among campus community. The main objective of this study is to model and assess travel distances covered by vehicles during CFDs and Normal Days (NDs) on the UTM campus, Johor, Malaysia using Shortest Path (SP). In this study, online and paper-based questionnaires were designed and distributed to UTM campus community to obtain residential addresses (origins) and parking lots (destinations). In total, 119 valid questionnaires were collected for the purpose of the study. Network datasets were built within a GIS database using ArcGIS Network Analyst Extension to perform SP analyses between the two centroids of origins and destinations. The measured travel distance costs of SP analyses during CFDs and NDs were compared using dependent t-test for paired samples and the test was not significant ($t(118) = 0.45$, P-value > 0.05). From the results, the study reveals that there are almost no difference in travel distances during CFDs and NDs, thus, the UTM CFDs initiative has no a particular effect on travel distances.

KEYWORDS

Car-Free Days; Shortest Path; travel distances; distance measurement methods; Campus Sustainability;

INTRODUCTION

In many parts of the world, many educational institutions introduced variety sustainability initiatives to improve environment and achieve campus sustainability [1]. Generally, campus sustainability is considered as issues of global concern on account of many activities are taking place on campuses that may have an adverse impact on the environment [2].

Different approaches were used to implement campus sustainability programs and reduce carbon emissions, as many cities around the world have adopted CFDs events [3]. At the moment, the CFDs are being practiced to increase sustainability modes of transportation and reduce vehicle emissions, although the first CFDs program was held to improve oil crisis in Switzerland [4].

University campuses are considered as a small city with unique communities on account of having different people with different backgrounds come together for study and work [5]. For that respect, decision makers of universities are encouraged to be proactive in improving campus sustainability by developing environmental regulations [2]. Therefore, many educational institutions around the world introduced sustainability initiatives to achieve sustainability goals [1]. Thus, it was addressed introducing CFDs initiative on university campuses [6]. Many universities accepted the world CFDs on 22 September, while others introduced their own environmental regulations to tackle overuse of vehicles on campuses [7].

The huge differences among educational institutions in terms of campus sustainability can be attributed using different approaches for achieving campus sustainability [1]. For instance, some universities in Malaysia such as UTM initiated a sustainable campus program to improve transportation, energy, air, water and waste management. To ensure reduction of carbon emissions and increase the level of awareness among campus community towards sustainability, UTM introduced the CFDs initiative. The UTM CFDs were officially launched in December 2016 and supposed to be continued on a monthly basis [8]. Meanwhile Universiti Kebangsaan Malaysia (UKM) officially commenced Sustainability Campus Programs (SCP) for conducting research in the field of sustainability [9].

Although CFDs were assessed using different assessment methods such as an interview survey by face-to-face method [4], survey questionnaires [6], qualitative research methods including literature review and observations [10], there is a limited number of published studies that used a Geographic Information System (GIS) analysis technique for the assessment of CFDs initiative. Therefore, there is a need that CFDs to be further assessed using the GIS technique. As GIS has significant contributions and offers decision support tool for the assessment of problems [11]. Therefore, the selection of an appropriate GIS analysis method for the assessment of the UTM CFDs is important.

It was investigated and compared, to a greater or lesser extent, different types of distance measurement methods for measuring between two points. These methods include SP, Euclidean distance, shortest network time, Manhattan distance and Minkowski distance metrics [12], [13], and [14].

In this study, SP methods are used to find the optimum shortest road distances between origins and destinations. Although it was argued that a road distance does not produce a model that can be implemented in spatial analytical modelling [15], SP was considered as more efficient and accurate road distance approaches

for measuring point-to-point shortest path problems [16].

METHODOLOGY

The study takes UTM campus as a study area (Figure 1); UTM has two campuses in Peninsular Malaysia: One branch is located in Kuala Lumpur, the capital of the country and the main campus is located in Skudai, Johor Bahru, Johor; where the study is conducted. Noted, UTM is a research university with a total population of 25,668 both academic staffs and students [17].

The main UTM campus was divided into different zones that are scattered around the campus. The inner circle of the campus, which is known as Lingkaran Ilmu contains the main buildings of the university that can easily accessible and promotes pedestrianism. It consists of faculties, administration buildings, main library, mosque and main halls. Hostels, staff residences, food arcades and recreational areas are located outside of the inner circle. Since different zones of the campus are occupying a total area of 1,222 hectares [18], different modes of transportation such as bicycles, personal cars, motorbikes and campus shuttles are used for the accessibility. Beside large areas of the campus, there are other factors can be attributed that the UTM campus community tend to use vehicles on the campus: (a) earth surface of the campus is not flat that makes the campus community challenge to walk or bicycle, and (b) raining or hot sunny days hinder walking and bicycling on the campus.

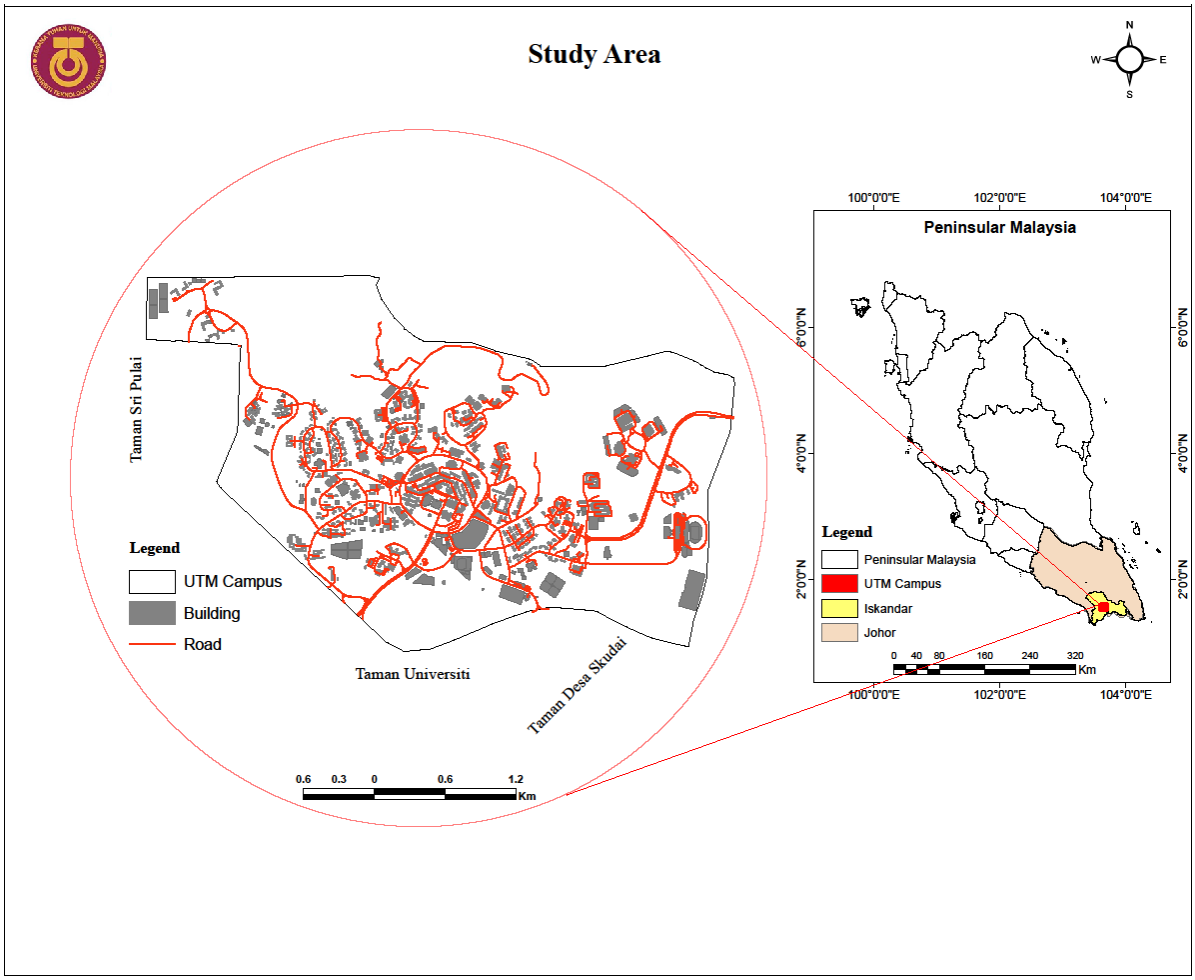


Figure 1: UTM main campus, Johor Bahru

To promote sustainable modes of transportation and increase the awareness of the campus community, a practical Car-Free Zone (CFZ) was chosen, which involves roads inside and around the inner circle (Lingkaran Ilmu) of the campus. There are four zones were chosen for parking during the CFDs event. The first CFZ involved large areas and covered whole the inner circle (Lingkaran Ilmu) and the second CFZ was reduced due to inaccessibility to different parts of the campus (Figure 2).

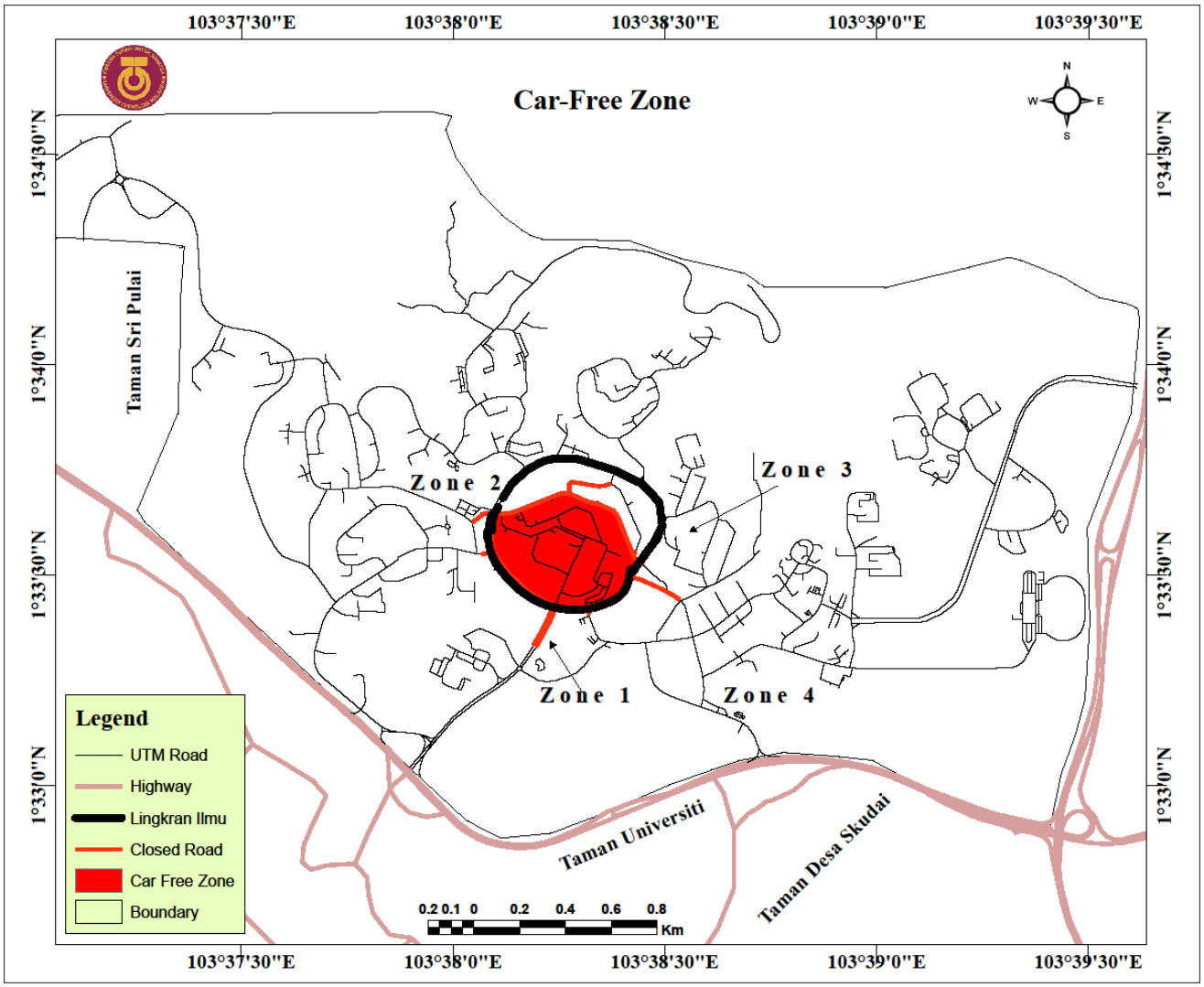


Figure 2: UTM Car-Free Zone (UTMCS 2017)

Selecting the UTM campus communities as the research population, a total of 119 UTM academic staffs and students were contributed for both online and paper-based questionnaire surveys. The primary data that were retrieved from questionnaire survey provided essential information about residential addresses and parking lots, although the precision of the collected data is dependent on the accuracy of respondents' answers. The study also utilized existing spatial data such as road networks and related spatial data, which are downloaded from the OpenStreetMap using ArcGIS Editor.

The study sets an appropriate coordinate system. Since it is needed to measure and map large-scale, road network datasets were expressed in local projected coordinate system that is GDM (Geodetic Datum of Malaysia) 2000 State Cassini Johor. ArcGIS Network Analyst Extension was utilized to perform SP between residential addresses and parking lots of research participants. In order to conduct the SP analyses, a network dataset was created within the geodatabase.

The respondents provided parking lots around their residential buildings (origins) and their usual destinations during CFDs and NDs. The centroids of origins and destinations were calculated using Geometry Calculator of ArcGIS software and the two centroids were located on a map as points. Therefore, the two points were defined as stops and added on the network datasets to represent an origin and a destination to find SP distances. Since the number of respondents was 119, a total of 238 times of SP processes for both CFDs and NDs travel distances were conducted. The SP layers for both CFDs and NDs were saved and exported into the geodatabase. The distance costs of each SP layer were calculated.

Since the travel distance data were collected from one sample of research population, the study used dependent t-test for paired samples to compare means of distances travelled during CFDs and NDs. The interpretation of this result determines whether the UTM CFDs reduce the travel distances on the campus.

RESULTS AND DISCUSSIONS

The respondents provided 30 destinations (parking lots) and 29 origins (24 residential addresses and 5 campus entrances). The residential addresses and destinations of the respondents were located on the map and calculated the centroid of parking lots using Geometry Calculator of ArcGIS software (Figure 3).

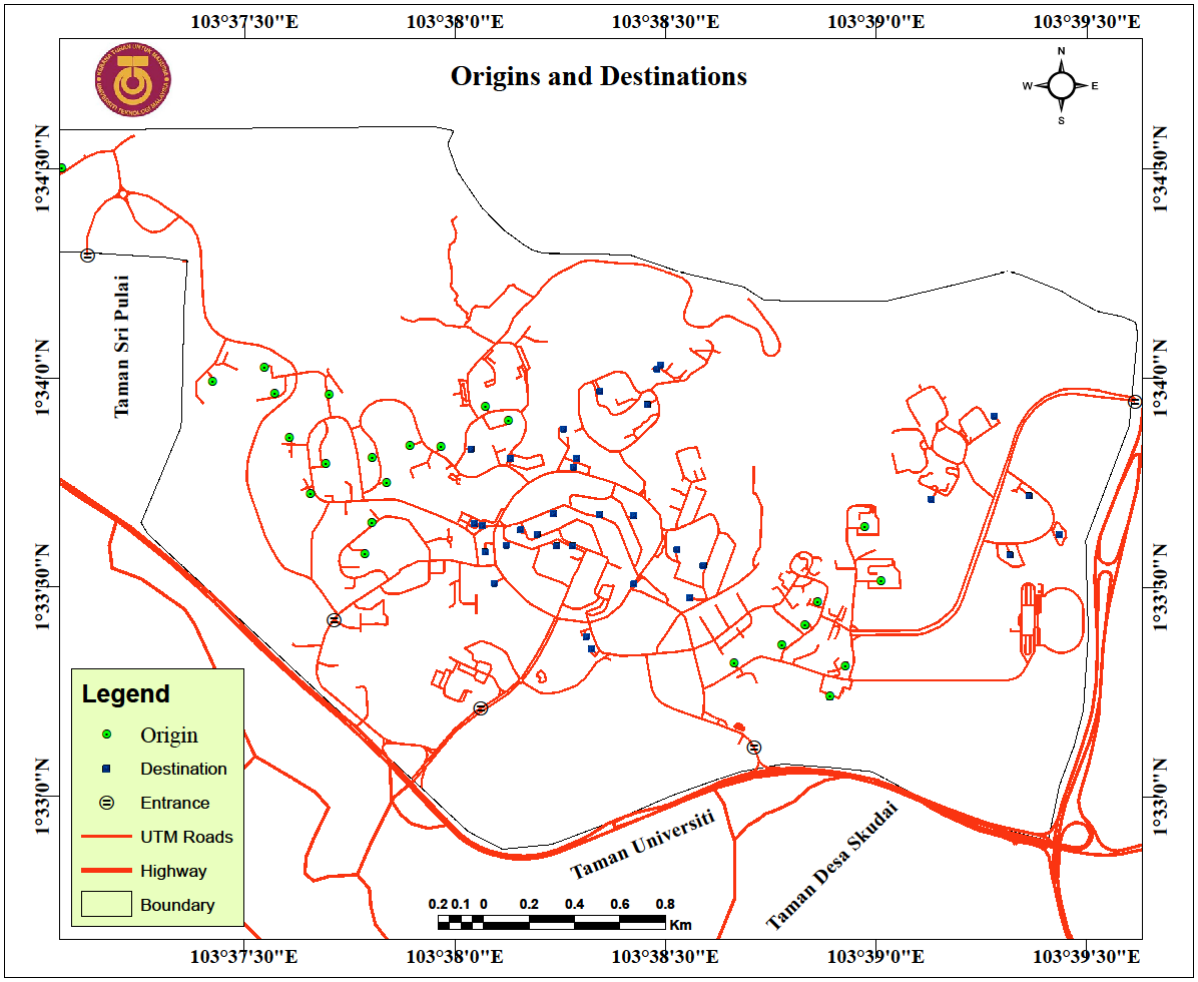


Figure 3: Origins and destinations of the respondents

TRAFFIC FLOW MAPS

The shortest travel distances between origins and destinations were measured using the SP methods for both CFDs and NDs. A total of 238 line features of SP were obtained for both NDs (Figure 4) and CFDs (Figure 5), and the number of the line features of each road were counted and used as frequency to symbolize traffic. For on-campus residents, the travel distances were measured from their residential hostels (origins) to destinations, whereas for off-campus residents, the travel distances were measured from pertinent campus entrances (origins) to destinations. The maps of total traffic flow were used to visualize and compare roads that heavily used and those used rarely on the campus. On NDs, the vehicle flow map clearly depicted that most respondents heavily used Ring Road (Lingkaran Ilmu), which is the main road of the campus that links faculties and administrative offices to hostels and other campus facilities. Therefore, it was observed that closing Ring Road during CFDs affects most traffic flow on the campus. Whereas on CFDs, vehicles were diverted away from the CFZ and the vehicles heavily used roads, which are nearby parking zones, such as Jalan Kolam, Jalan Cahaya and

Lingkok Universiti (Figure 6). These results show that the overuse of some roads may cause traffic jams around the allocated parking zones for the CFDs.

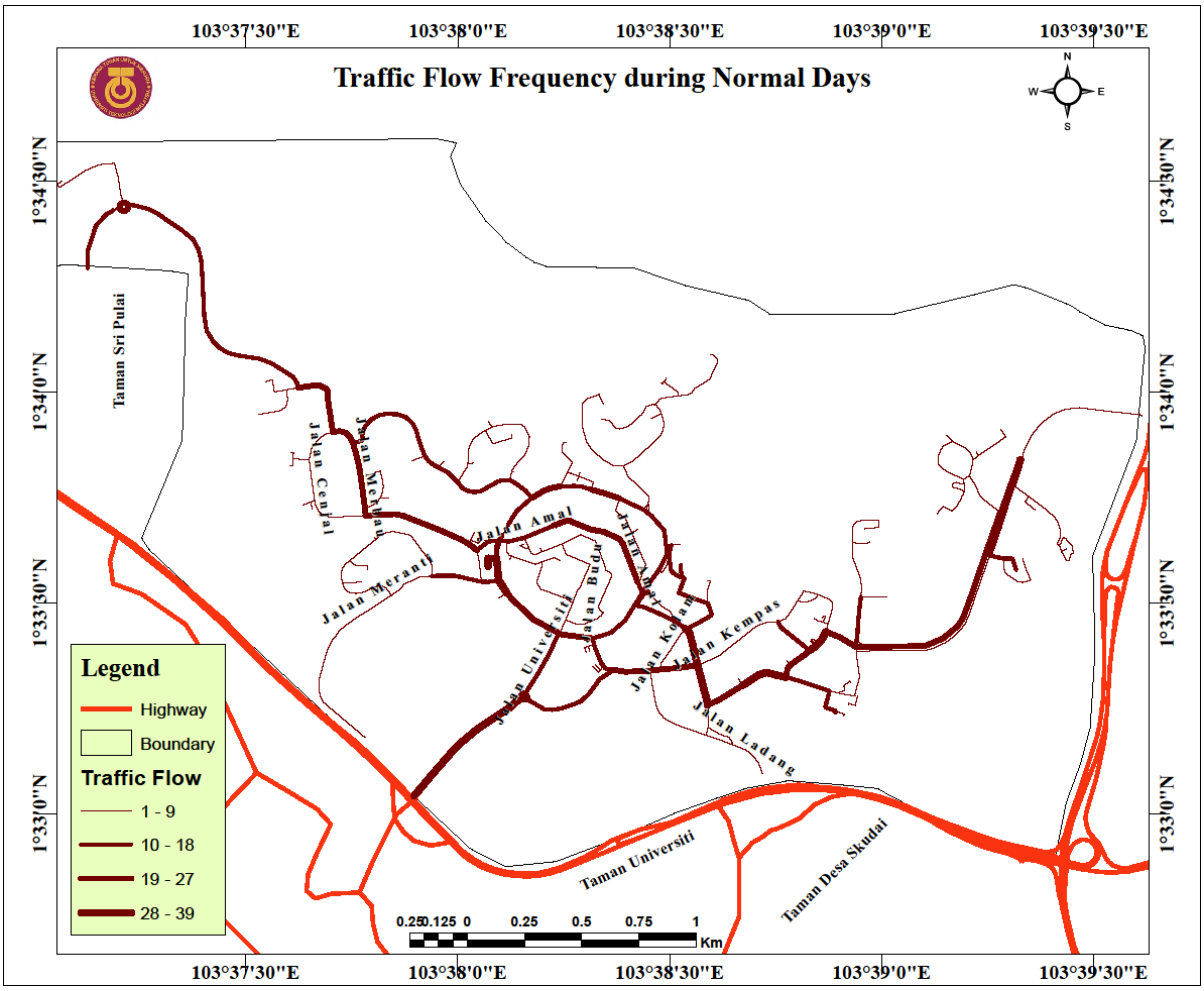


Figure 4: Traffic flow frequency on NDs

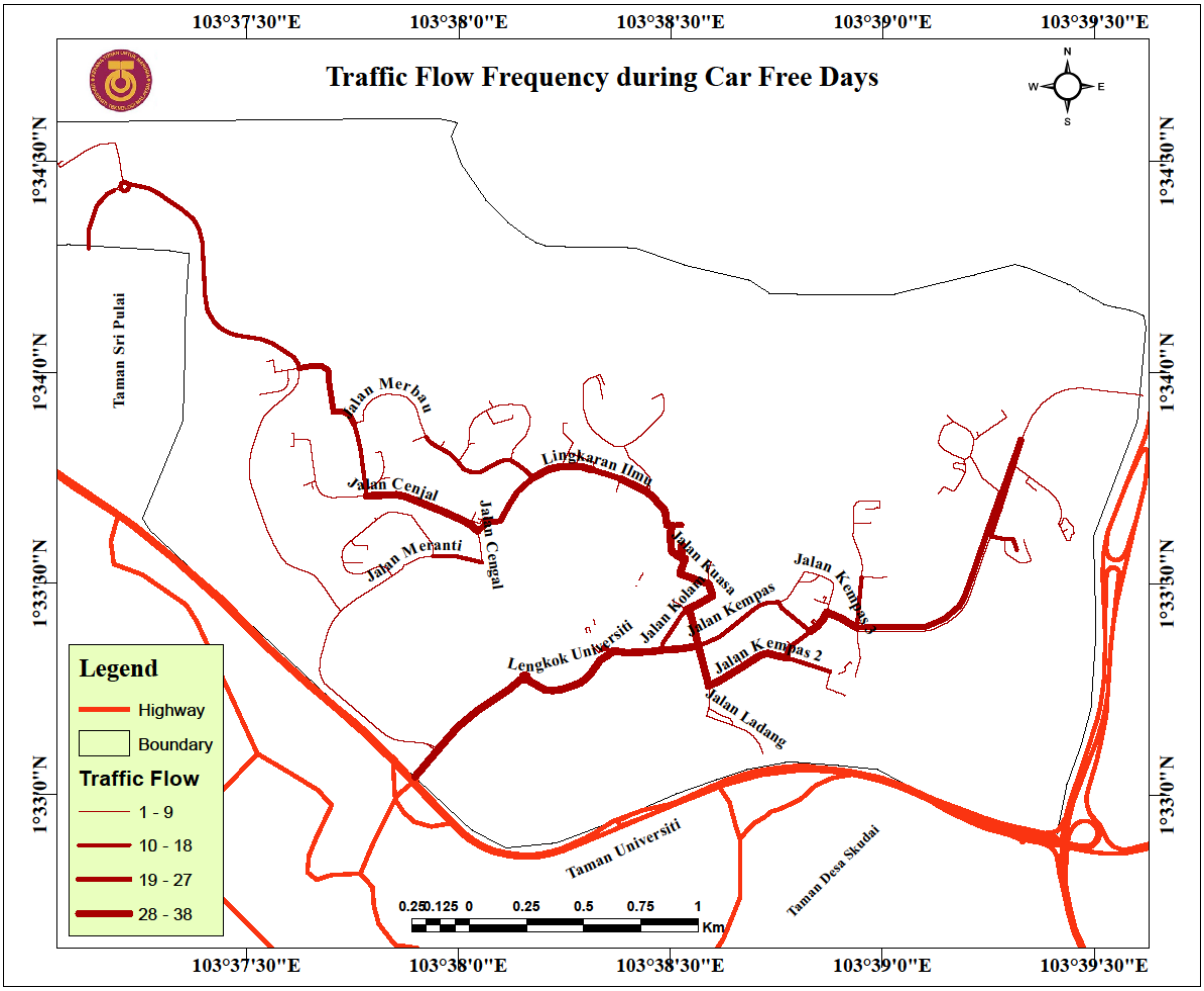


Figure 5: Traffic flow frequency during CFDs

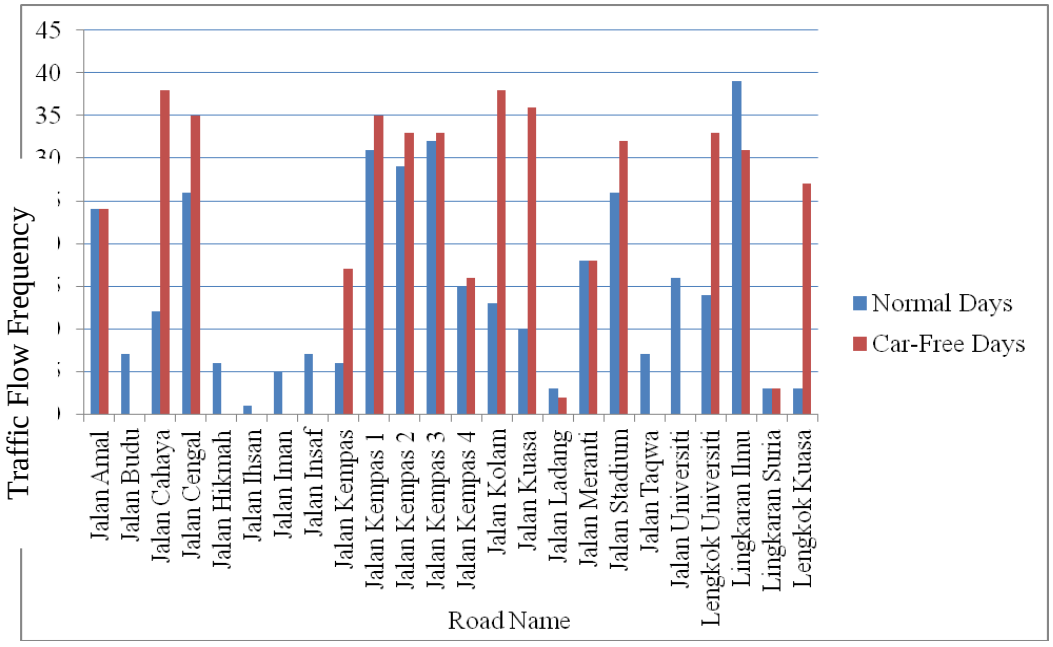


Figure 6: Traffic flow frequency

MEASURING TRAVEL DISTANCES

A total travel distance of 296,401 m (296.4 km approximately) was measured during NDs using SP methods (Table 1), whereas, a total travel distance of 296,334 m (296.3 km approximately) was measured during CFDs. From the surveys, 53 of the respondents were off-campus residents and their travel distances were measured from their pertinent campus entrances to their destinations. Meanwhile, 66 of the respondents were on-campus residents and their travel distances were measured from their parking lots to their destinations.

Table 1: Measuring travel distances using a shortest path

Type of Origins	No. of Respondents	Travel Distances During NDs (m)	Travel Distances During CFDs (m)
Entrances	53	142,449	147,388
Hostels	66	153,952	148,946
Total	**119**	**296,401**	**296,334**

COMPARISON OF TRAVEL DISTANCES

Data exploration was conducted to check whether the travel distances are normally distributed since the dependent t-test for paired samples assumes that the data are normally distributed [19]. However, it was observed that the travel distances data violate the normal distribution, so the data were transformed by multiplying Log10. The transformed data were tested using a Shapiro-Wilk's test for normality that is one of the general normality tests that are designed to detect all departures from normality [20]. Therefore, the Shapiro-Wilk's test revealed, where P-value > 0.05. Having a Null Hypothesis; there is no difference in travel distances during CFDs and NDs, the dependent t-test for paired samples was conducted and revealed that travel distances using SP methods during CFDs showed that Mean = 3.33, Std. Deviation = 0.24. Meanwhile for NDs, the results of Mean = 3.34, Std. Deviation = 0.21, in which the results are similar with t(118) = 0.45. Therefore, the test is not significant (P-value > 0.05). In summary, based on the statistical results, the travel distances during CFDs and NDs are same (Figure 7).

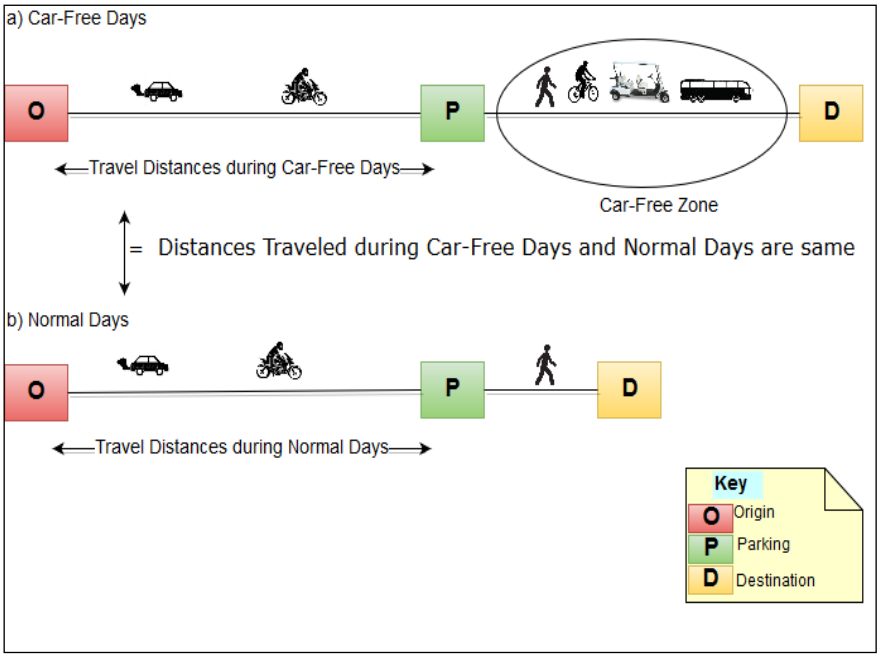


Figure 7: Travel methods during CFDs and NDs from origins and destinations

CONCLUSION

Although there are many distance measurement methods in GIS, the use of shortest path methods for measuring travel distances is considered a realistic technique for measuring from origins to destinations on two-dimensional (2D) maps. The UTM CFDs initiative was intended to reduce travel distances since long travel distances are associated with the increase of vehicle emissions. However,

the present study showed that there are almost no differences in travel distances covered by vehicles on the UTM campus during CFDs and NDs. On the other hand, the traffic flow maps showed that the roads with the highest traffic flow; therefore, these roads require proper management to reduce traffic jams during both CFDs and NDs. It was suggested that the UTM campus authority to recreate a new area for CFZ.

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