Road Speed Profile: A Case Study of Pracha Uthit Road

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Abstract

The objective of this research is to study the speed profile of Pracha Uthit Road from Pracha Uthit Intersection to Na Luang Intersection in order to understand traffic conditions along the study corridor. Heat maps were created to identify the locations and time periods with traffic congestion. The data used for this study were obtained from Thai Intelligent Traffic Information Center (iTIC), which include the information from the Global Positioning System (GPS) equipment installed on public taxis. From the analysis results, it is found that the traffic congestion pattern throughout the corridor changed according to the time of day where there was recurring congestion at some locations. The speed profiles obtained from this research can be used to pinpoint roadway bottlenecks and apply proper mitigation measures for the roadway sections, such as a reversible lane strategy. Knowing the speed profile allows one to efficiently determine the operational boundary as well as the operational time of the managed lane application. The method used in this study can be used to assess roadway speed profiles as a tool to help decision-makers effectively solve traffic congestion problems in a road network.

Keywords: GPS, Heat map, Speed Profile, Traffic congestion, Traffic problems

1. Introduction

In Thailand, a high-resolution speed heat map has not been popularly used as a tool to identify locations with traffic congestion. Unlike other countries such as the United States of America (USA) and the United Kingdom (UK), the speed heat map application has long been a conventional strategy in traffic management [1]. A speed heat map is a tool to visualize traffic conditions along a corridor by displaying speed values for each small section during each hour, which are then converted into colors indicating speed level from low to high. The speed level in the heat map directly corresponds to traffic conditions. Low speed values, usually represented in red color, indicate a traffic congestion spot while high speed values, with green color, indicate uncongested conditions. In general, speed heat maps can be used to provide information about the congestion location, congestion period, and length of the congestion.

In this study, we conducted a speed study and prepared speed heat maps for Pracha Uthit Road from Pracha Uthit intersection to Na Luang intersection, a total distance of about 3.1 km. Pracha Uthit Road is a 4-lane road that serves traffic in Rat Burana and Thung Khru districts. The road regularly experiences traffic congestion during the morning peak hours in the inbound direction and vice versa during the evening peak hours [2]. There are various types of land use along the study road such as residential areas, schools, university, commercial areas, and local post office. Therefore, a large number of travel demand is generated and attracted by these land uses creating traffic congestion on the adjacent roads that serve them. Based on the information from Bangkok Metropolitan Administration (BMA), traffic jams on this road usually occur between 7:00-9:00 a.m. and 4:00-7:00 p.m. [3]. However, the traffic congestion on Pracha Uthit Road can be varied both by location and time throughout the day, which makes it very difficult to manage the congestion problem. The use of speed heat maps can help pinpoint congested spots and time periods. Therefore, this study aims to understand how to prepare speed heat maps and use their data to solve traffic congestion problems.

1.1 Objectives

1. To learn how to access a speed profile through a development of speed heat maps.

2. To understand traffic patterns during different time periods on Pracha Uthit Road.

3. To identify potential improvements and suggestions for the traffic congestion management on Pracha Uthit Road Font size and alignment

1.2 Study Scope

1. This study focuses on a traffic speed on Pracha Uthit Road between Pracha Uthit and Na Luang intersections as shown in Fig. 1.

2. This study analyzes GPS data to access traffic speed profile during different time periods on Pracha Uthit Road between Pracha Uthit Intersection and Na Luang Intersection.

1.3 Expected Outcomes

1. Understand traffic bottleneck locations, duration, and time of the traffic congestion on Pracha Uthit Road and use speed heat maps to detect recurrent and non-recurrent problems.

2. Development of suggestions to improve traffic congestion on Pracha Uthit Road.

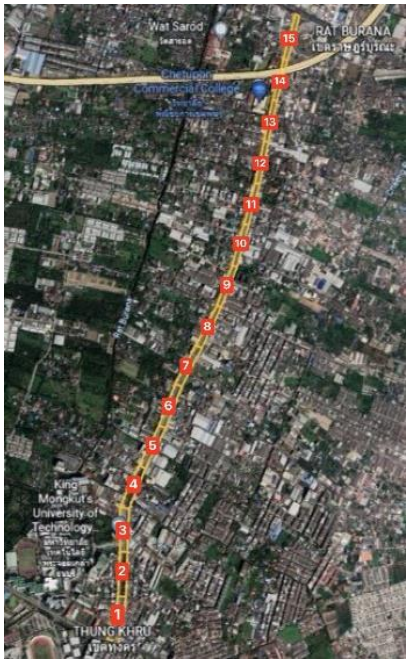

Fig. 1 Pracha Uthit Road between Pracha Uthit Intersection and Na Luang Intersection

2. Literature Review

2.1 Heat Maps

A heat map is a method to visualize data by displaying data values as colors in the 2D graphs [4]. The color is used to represent scale level that warm tones going under the red-yellow spectrum indicate an increase of data, while cool shade going under the blue-green spectrum indicates a decrease of data as shown in Fig. 2 [5].

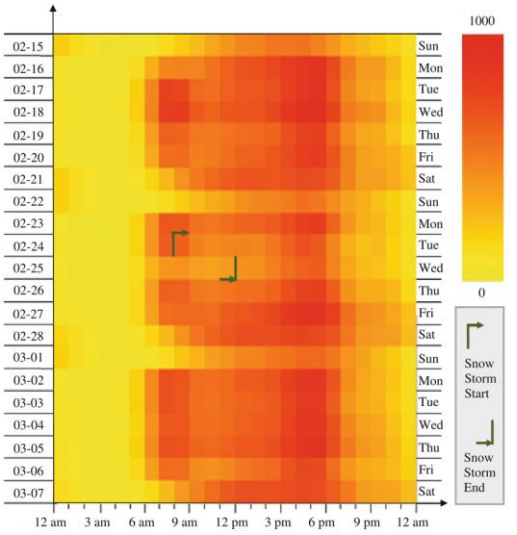

Fig. 2 Example of Heat Map used to Represent Traffic Congestion Analysis

2.2 Distance from GPS Coordinates

The longitude and latitude coordinates on the map can be located by pointing on the desired location. Once the latitude and longitude values are obtained, the distance can be calculated using Equations 1, 2, and 3 [6].

$$A = sin^2(\Delta\varphi/2) + cos\ \varphi 1 \cdot cos\ \varphi 2 \cdot sin^2(\Delta\lambda/2) \quad (1)$$

$$C\ (Radian) = 2 * atan2(\sqrt{A}, \sqrt{(1-A)}) \quad (2)$$

$$D\ (km) = R * C \quad (3)$$

Where φ is latitude (degree) λ is longitude (degree) R (radius of the earth) = 6371 km. Equation 1 is used to find A and then A is used in Equation 2 to find C. The distance can be calculated by multiplying C with the radius of the earth.

2.3 Speed Profile

Speed profiles are used to identify and study where there is velocity variability along the road segment. Examples of technology that is often used for measuring speed, travel time and route choice is Global Positioning System (GPS) because GPS data is more accurate when road sections have different geometric design. For application of speed profile, it can be used to modify the road design to reduce accidents by using information of speed profile [7].

2.4 Studies on Speed Profile

Yu et al. (2020) studied the estimation of traffic speed across the network. It uses route data generated by city-wide vehicles that have GPS-enabled smartphones. A cell-based map-matching technique has been proposed to link the trajectory of a vehicle with the geometry of the road and create a network-wide spatio-temporal speed matrix. The data restriction was solved using the Schatten p-norm matrix completion algorithm, which was able to minimize the speed estimation error even without the high rate of data. Chengdu, China, is a case study indicating that the problem of estimating traffic state in large networks with missing data can be solved where algorithms work well even with losing data in a matter of hours. This research can help to follow and visualize the dynamics of network traffic in a congestion map as shown in Fig. 3 and Fig. 4 [8].

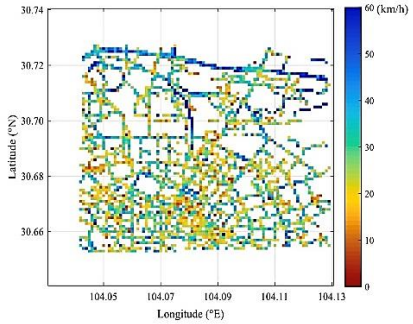

Fig. 3 Network-Wide Traffic Speed Map on AM Peak (8:00–8:05)

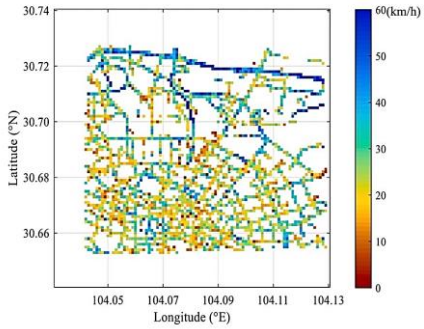

Fig. 4 Network-Wide Traffic Speed Map on PM Peak (18:00-18:05)

Francisco J. Camacho-Torregrosa et al. (2012) studies methods for assessing road safety at both the design and redesign stages of two-lane rural roads to reduce road fatalities. The method is based on the uniformity analysis of the geometric design of the road. This is a measure of the safety level of a two-lane rural road. The conformity model is based on continuous consideration of operating speed profiles as shown in Fig. 5. An innovative method of collecting GPS data made it possible to create construction models. Based on continuous running speed profiles recorded from individual drivers, researchers were able to observe the actual behavior of the drivers and developed a more accurate operating speed model based on spot-speed data collection. The working speed profile was created for a two-lane rural road section in Spain. The model allows estimation of the number of road segment collisions using geometric design concordance calculations [9].

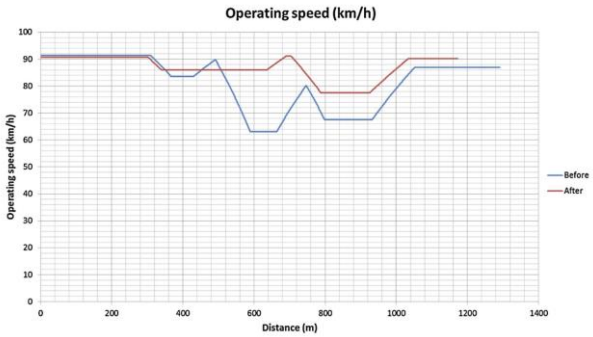

Fig. 5 Operating Speed Profiles for the Existing Road and the Redesign Proposal

3. Methodology

3.1 Research Procedure

To achieve the objectives of this research the researchers used the following procedures and methods for this project. Start by reviewing the literature and researching for speed profiles data. The research team used methods, tools, and collected secondary data to create a speed profile for Pracha Uthit Road as described in the following section. The overall study process described above can be summarized as shown in Fig. 6.

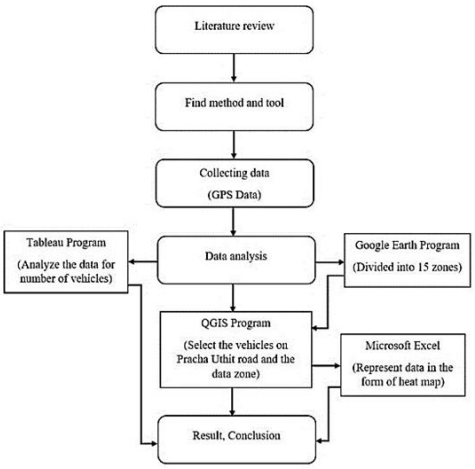

Fig. 6 Research Procedure

3.2 Data Collection

Due to the Covid-19 outbreak, unusual working and school conditions had significant impacts on the number of vehicles on roads as it greatly reduced from normal circumstances. Thus, the study results rely on only historical GPS data prior to the pandemic.

The GPS data were obtained from Thai Intelligent Traffic Information Center (iTIC) for the time period before Covid-19 pandemic. The information obtained is a collection of travel data from individual taxi that has been equipped with GPS devices. In this project the authors selected data for 14 day in September 2018. The date selected is the day that university and school are open and it is not a holiday, as shown in Table 1.

Table 1 Date Selected for Study

Date selected for study	
Monday	03/09/2018
	10/09/2018
Tuesday	04/09/2018
	18/09/2018
Wednesday	05/09/2018
	12/09/2018
Thursday	06/09/2018
	13/09/2018
Friday	07/09/2018
	14/09/2018
Saturday	08/09/2018
	15/09/2018
Sunday	09/09/2018
	16/09/2018
Total	14 Day

3.3 Data Analysis

For this part, the GPS data were processed and analyzed based on necessary information including timestamp, latitude, longitude, and travel direction of vehicle.

3.3.1 Data Calculation

Based on the GPS data, a distance can be calculated from latitude and longitude information by using Equations 1 and 2. After getting the distance, a velocity can be calculated using Equation (4).

$$Velocity = distance\ (km) / time\ (hr) \quad (4)$$

3.3.2 Study Road Segmentation

The total distance between Pracha Uthit intersection and Na Luang intersection is approximately 3.1 km. For purpose of this study, we divided the study section into 15 zones with a distance about 200 m per zone as shown in Fig.1.

3.3.3 Tableau Program

According to a nature of GPS data that are associated with a large number of data records and coverage, it is necessary to extract data for the study locations. For this study, a Tableau program is used to analyze and extract GPS data for a number of vehicles on Pracha Uthit Road for the selected time period.

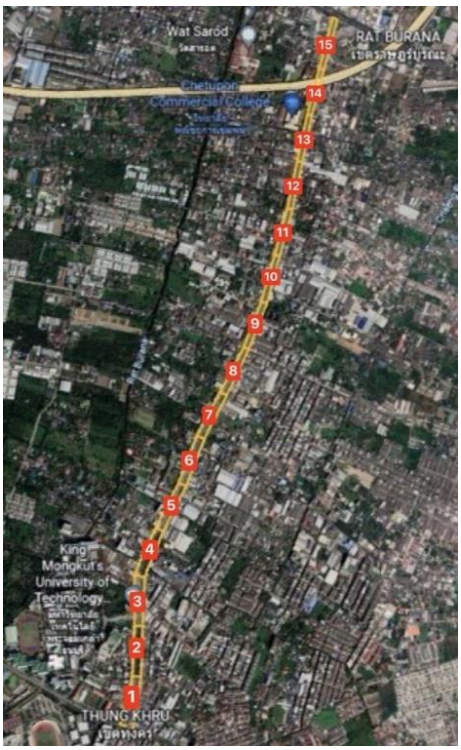

Fig. 7 Zone of Pracha Uthit Intersection to Na Luang Intersection

3.3.4 Google Earth Program

Use Google Earth to measure the distance of Pracha Uthit Road. And find the latitude and longitude coordinates to divide the zone of roads for use in the created heat map.

3.3.5 QGIS Program

In this study, QGIS was used to select the car that is located within the study sections. First, the GPS data were extracted for the information of interest on Pracha Uthit road. Second the extracted data were assigned into the pre-specified zones based on their geographic location and heading direction.

3.3.6 Create Speed Heat Map

A heat map that represents the average speed of the vehicles on Pracha Uthit Road can be created by using a condition formatting feature in Microsoft Excel to convert all speed values into pre-defined colors.

4. Results

4.1 Results for GPS Sample Data

From the taxi's GPS data, which cover the area for the entire country, It is necessary to extract the data that are located on Pracha Uthit Road between Pracha Uthit intersection and Na Luang intersection. For the extraction process, QGIS was used as a tool to obtain such data. The raw data obtained from iTIC were collected from taxis equipped with GPS. The extracted GPS data used in this study are those verified as ones from the taxis that were actually running in the traffic stream on Pracha Uthit road during the specified dates and time periods, which can be a representative of the overall traffic that runs within the study corridor.

Table 2 illustrates the total number of GPS data on Pracha Uthit Road during the selected time period. The results in Table 2 show the amount of data and the number of vehicles (engine running) each day for 2 weeks. There are approximately 275 – 375 taxi samples with a total of 1,675 – 2,979 GPS data points for each day during the analysis period.

Table 2 Number of Taxis from GPS on Pracha Uthit Road

Day	Total number of data (engine running)	Total number of vehicles
03/09/2018	2,824	330
04/09/2018	2,815	316
05/09/2018	2,729	307
06/09/2018	2,652	331
07/09/2018	2,623	315
08/09/2018	2,085	320
09/09/2018	1,675	294
10/09/2018	2,396	277
18/09/2018	2,606	275
12/09/2018	2,806	287
13/09/2018	2,447	316
14/09/2018	2,979	375
15/09/2018	1,942	302
16/09/2018	1,814	320

4.2 Zone Assignment

Fig. 8 shows the results for the GPS data that are assigned into zones from a data extraction in QGIS. There are 15 Zones with a distance of 200 meters for each Zone between Pracha Uthit intersection and Na Luang intersection.

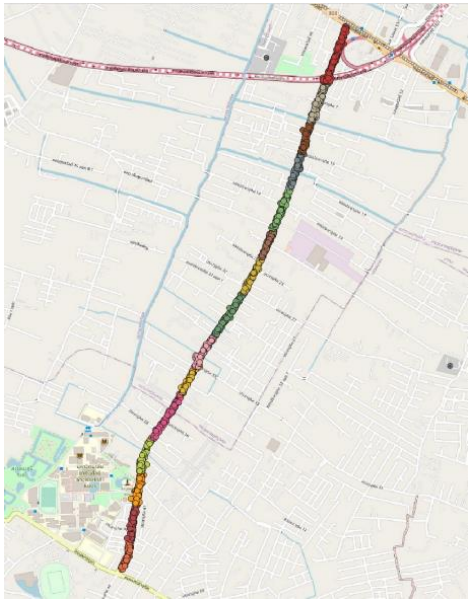

Fig. 8 QGIS Zoning from Pracha Uthit Intersection to Na Luang Intersection

4.3 Results for Speed Heat Maps

4.3.1 Speed Heat Map for Inbound Direction

From the generated heat maps during the selected week, there are some locations that do not have speed data. Fig. 9 shows the average speed for inbound Pracha Uthit Road. Inbound Pracha Uthit Road has an average speed between 0 - 44 km/hr throughout the road, 3 - 19 km/hr during morning rush hours, and 1 - 27 km/hr during evening rush hours. It has a maximum average speed of 44 km/hr at nighttime and 28 km/hr during the daytime. The lowest average speed (0 – 10 km/hr) occurs in Zone1 (Na Luang Intersection), Zone 2 (Pawnshop Pracha Uthit 36), and Zone 3 (KMUTT). These 3 sections have relatively low average speed at all times during the day. There are activities in these congested zones such as the university entrance (Zone 3), which has vehicles in and out all day, resulting in low speeds throughout the day. The average speed during the morning rush hours is less than that of evening rush hours, which is consistent with the peak travel direction during the morning rush hours.

From the heat maps for the morning (Fig. 10) and evening (Fig. 11) time periods, a recurring traffic congestion clearly occurs between Zone 1 (Na Luang Intersection) and Zone 3 (KMUTT) for everyday, with an average speed of approximately 2 – 15 km/hr. For the morning period on weekdays, the inbound direction has

an average speed of 2 – 18 km/hr. On weekends, Zone 4 (Pracha Uthit 30) to Zone 15 (Pracha Uthit Intersection) have an average speed more than that on the weekdays, with an average speed in the range of 17 – 33 km/hr as shown in Fig. 10.

For the evening period, a recurring traffic congestion occurs everyday in Zone 1 (Na Luang Intersection) to Zone 3 (KMUTT), with an average speed of approximately 0 – 14 km/hr, and in Zone 15 (Pracha Uthit Intersection), with an average speed of 11 – 20 km/hr as shown in Fig. 11.

4.3.2 Speed Heat Map for Outbound Direction

From the generated heat maps in this direction, some zones do not have speed data for the analysis. Fig. 12 shows the average speed for outbound Pracha Uthit Road. Outbound Pracha Uthit Road has an average speed of 1 - 55 km/hr throughout the study sections, 4 - 30 km/hr during the morning rush hour, and 6 - 24 km/hr during the evening rush hour. It has a maximum average speed of 55 km/hr at nighttime and 39 km/hr during the daytime. It is found that the lowest average speed occurred in Zone 15 (Pracha Uthit Intersection), Zone 14 (Underpass), and Zone 13 (Post Office), with a range between 1 – 36 km/hr. These 3 sections have low average speeds almost at all times during the day.

During the morning rush hours, it is found that Zone 8 (Pracha Uthit 27/2) has the highest average travel speed. And during the evening rush hours, the highest average speed occurs in Zone 9 (The Privacy Condo). The average speed during the morning rush hours is more than that of evening rush hours from Ratburana Market to Na Luang Intersection, which is consistent with the peak travel direction of the road during the evening rush hours.

When focus on the morning and evening peak period for each day of the week as shown in Fig. 13 and Fig. 14, respectively, there is a recurring congestion in the morning peak period from Zone 13 (Post Office) to Zone 15 (Pracha Uthit Intersection), with an average speed of approximately 2 – 20 km/hr as shown in Fig. 13.

For the evening peak period, there is a recurring congestion from Zone 12 (Ratburana Market) to Zone 15 (Pracha Uthit Intersection), except Zone 13 (Post Office) on Sunday, with an average speed of approximately 3 – 16 km/hr as shown in Fig. 14.

4.3.3 Speed Heat Map on Pracha Uthit Road

From the traffic congestion problems detected for the study corridor, the red zones from the heat maps, which indicate low-speed points, likely correspond to activities in the areas such as on-street parking, busy driveways and junctions, and a presence of commercial retails. Therefore, this could lead to a process to identify suitable mitigations and traffic management strategies according to the speed profile suggested by the heat maps. For the congested areas that are found from the heat maps, there are 3 low-cost improvement alternatives for the study corridor.

- Reversible Lanes

Reversible lane is a method that reverses a travel lane to the opposite direction to increase roadway capacity for the heavy traffic direction. This method would help the traffic move faster and reduce traffic congestion. For traffic practitioners, operational time and boundary of reversible lanes can be determined from heat maps.

- Prohibit On-Street Parking during Peak Period

There has been on-street parking blocking traffic lanes on Pracha Uthit Road throughout the day. Based on the time periods and locations of the hot spots identified in the heat maps, a reguration for on-street parking can be revised to prohibit a roadblock during the specified times and locations to increase traffic flow along the corridor.

- Avoid using the Road during Traffic Congestion

Using heat maps let us know when and where the traffic is congested on the roads. The speed profile information from heat maps can be used to advise travelers to plan their trips in advance to avoid congestion.

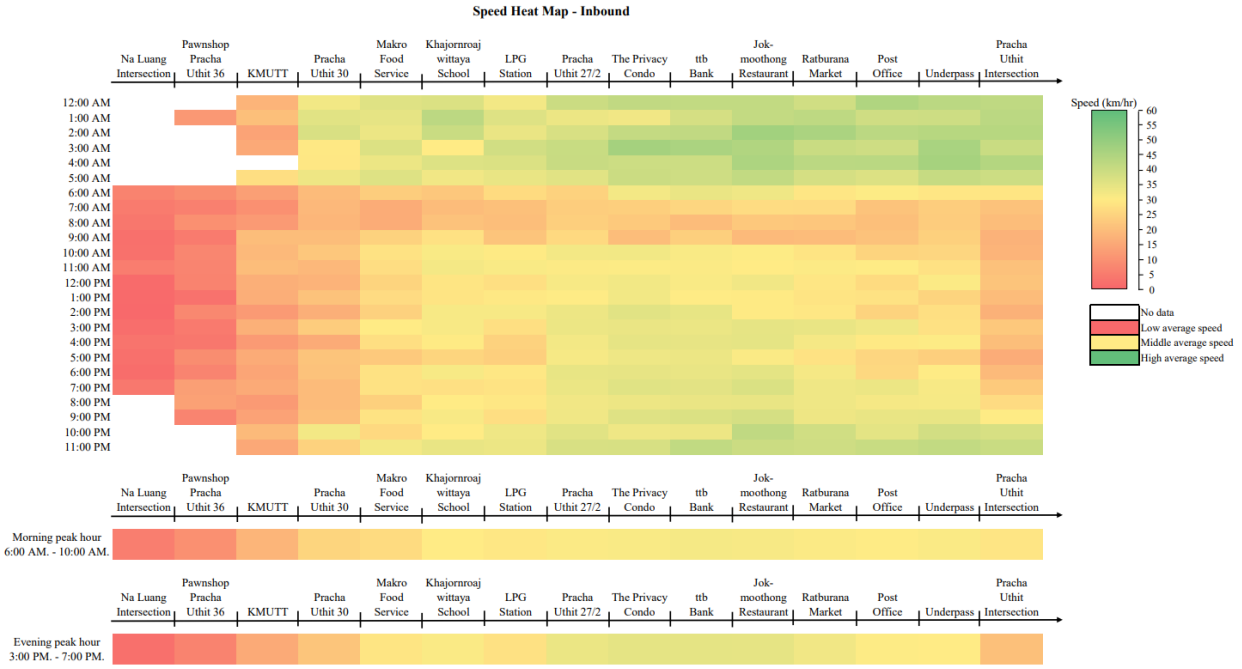

Fig. 9 Speed Heat Map of Inbound Pracha Uthit Road

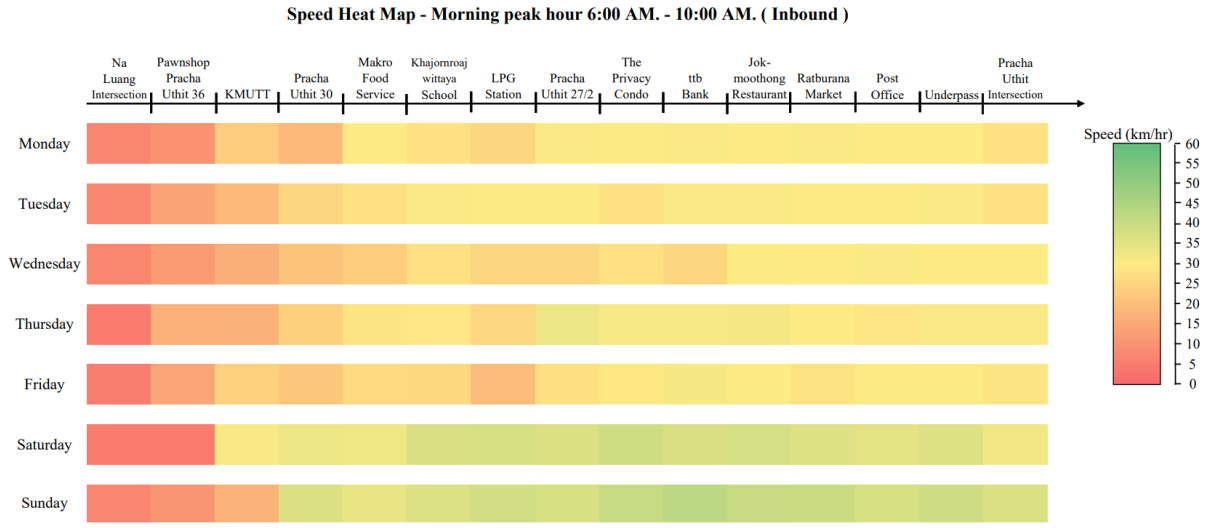

Fig. 10 Speed Heat Map for Morning Peak Period between 6:00 AM. - 10:00 AM. (Inbound)

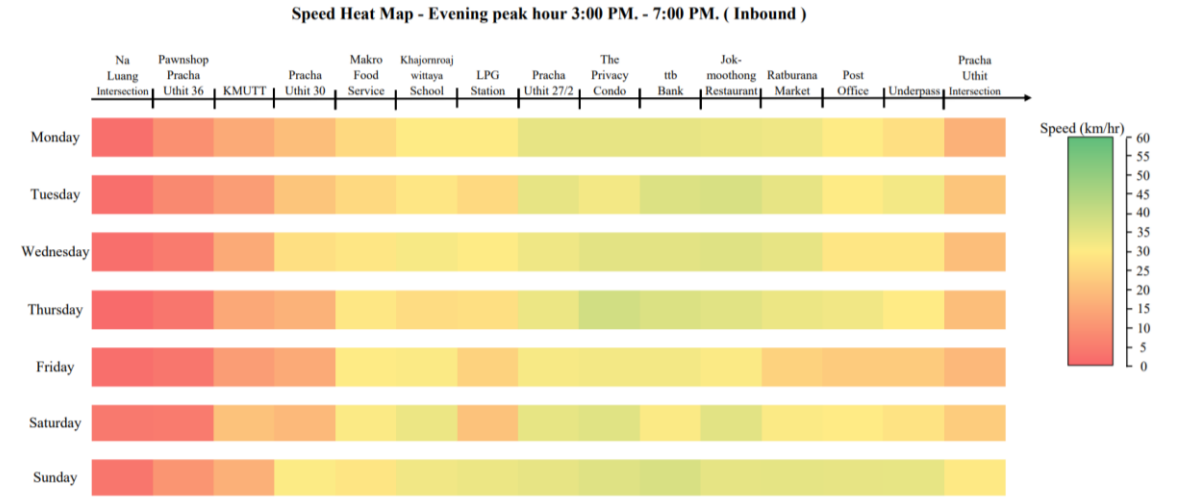

Fig. 11 Speed Heat Map for Evening Peak Period between 3:00 PM. - 7:00 PM. (Inbound)

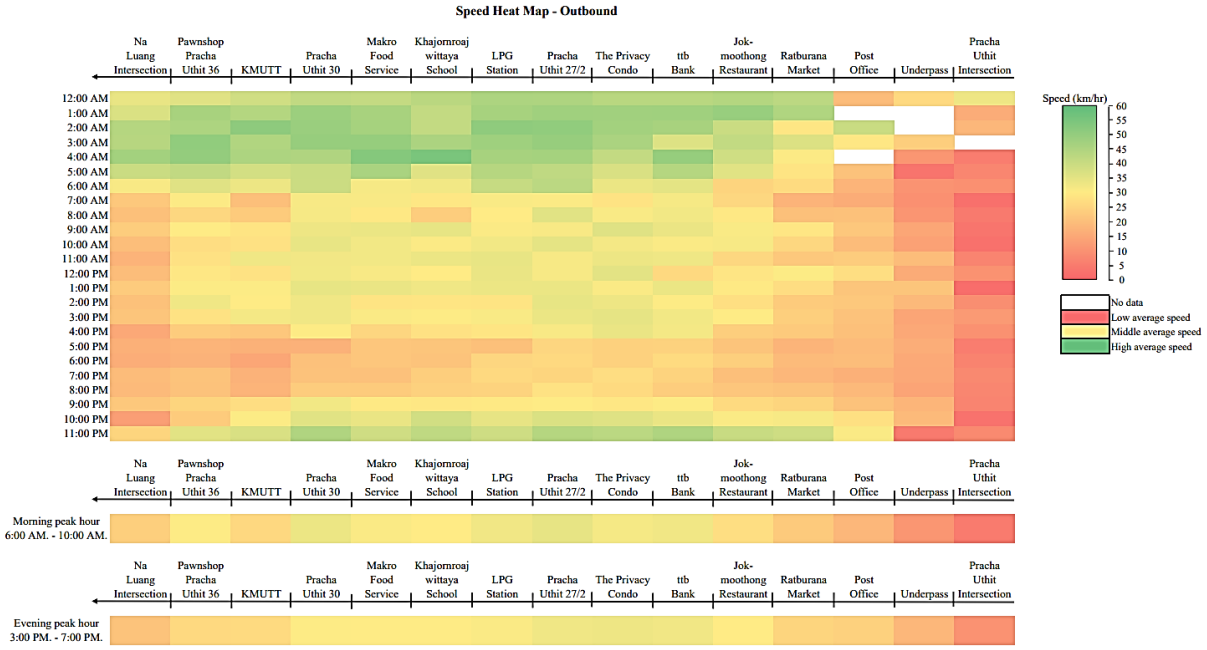

Fig. 12 Speed Heat Map of Outbound Pracha Uthit Road

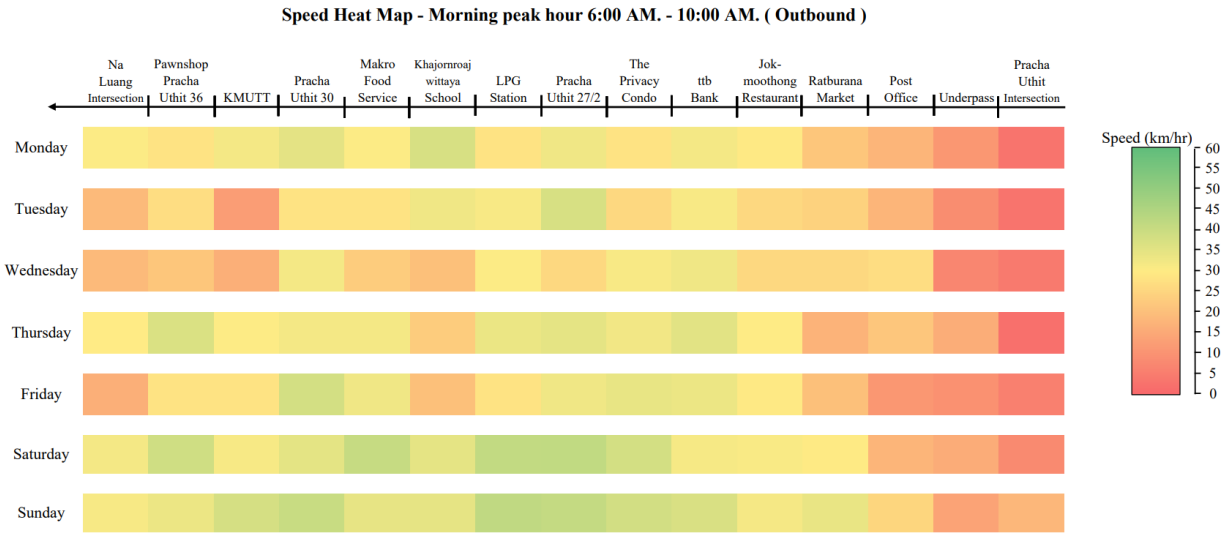

Fig. 13 Speed Heat Map for Morning Peak Period between 6:00 AM. - 10:00 AM. (Outbound)

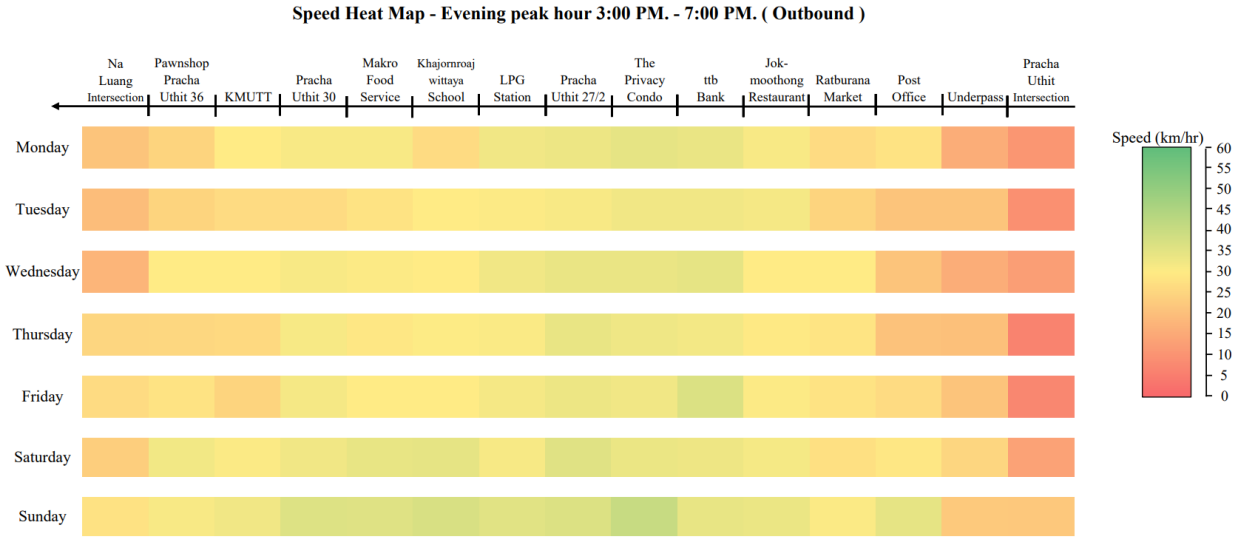

Fig. 14 Speed Heat Map for Evening Peak Period between 3:00 PM. - 7:00 PM. (Outbound)

5. Conclusions

Pracha Uthit Road has a high traffic volume passing through daily and it has been known as one of the congested routes for commuters. Therefore, it is important to access a speed profile through high-resolution speed heat maps and understand traffic patterns during different time periods to identify potential mitigations and suggestions for a traffic congestion management on Pracha Uthit Road.

For the congested areas that are found from the heat maps, alternative low-cost improvements can be an enforcement for on-street parking prohibition during the congested time shown in the heat maps, providing information for travelers to avoid using the road during traffic congestion periods, and the use of reversible lane, which the operation time, distance, travel direction can be determined from the heat maps.

The data used in this study are based on GPS from taxis, which we found that some data were not available for the selected analysis period and some data were not applicable due to unexpected stationary vehicles. This could be corrected by using GPS data from different weeks to create a daily heat map. Other speed data collection methods could be considered to overcome the data poor problem such as using traffic sensors or vehicle probes, but these methods would require substantial efforts and budget in order to fill in for a complete data.

Acknowledgement

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