A Novel Method for Travel System Patterns

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Abstract:

Due to population growth in urban areas, especially in the capital cities in developing countries, the use of private vehicles are increasing, leading to many problems such as congestion, pollution, noise, long travel time, high travel cost and more side effects. In such circumstances government policy would encourage people to use public transportation. In the meantime, employing the Intelligent Transport System consisting of two parts including private sector and public sector by predicting the dynamic travel time, can help the travelers to be aware of the latest traffic information. To achieve this objective, the calculation of traffic flow, demand of passenger and transport means availability are vital. The double constraint gravity model is a crucial methodology for predicting the origin destination matrix. This paper represents a Travel System Pattern (TSP) based on proposed methodology. TSP tries to let the travellers and authority know about the best travel route with considering the shortest dynamic travel time information. For this purpose the travellers are able to be aware of the travel time and other details of travel route via the internet or SMS system. Hence, a case study based on an actual public and private network in Kuala Lumpur, Malaysia is chosen as a case study area. The result shows that the accuracy of the proposed method indicated reasonable R2 of 0.926 for the evening rush traffic period. This indicates that the TSP developed in the present study is a reliable and suitable tool to guide the travellers and companies.

Keywords: OD matrix, traffic assignment, multi-modal, ITS, delay time.

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1. Introduction

Due to the dramatic increase in the number of vehicles, traffic congestion has become an increasingly serious problem in large cities around the world [Shokri et al. 2009]. This is an important finding in terms of policy implication. Ismail and Hafezi 2011 carried out a similar study for shopping trips, where consumers' response to the introduction of paid parking at the regional shopping mall is analyzed. The results suggest that changes in expenditure can affect shopping location, duration, frequency as well as mode choice. In many capital cities including Kuala Lumpur, the increasing number of car users involved in crashes and the associated injury travel demand management receive increasing attention for the potential to improve urban transport problems with undertaking various solutions to solve this problem [Hafezi and Ismail, 2012].

A multi-modal or inter-modal urban transportation system can be defined as the use of two or more modes involved in the movement of people or goods from origin to destination [Dewitt and Clinger, 2000]. Based on this, mode choice decision is a technique that provides an opportunity to explore and utilize different modes of transportation such as train and bus to reach their destination on time. Improvements in public transport operations alone will not necessarily persuade people to change their selected mode. Travelers need to be informed of what is available. Traditionally, public transport companies issue information on times and fares of their services, primarily through timetables and fares tables; these were generally complemented with marketing initiatives, including special offers [Hafezi and Ismail, 2011a and Hafezi and Ismail, 2011b].

Possible levels of analysis for predicting changes in ridership are shown in Table 1. Forecasting demand could be assessed using Origin-destination matrices along with a multinomial logit model to give a decision as to the access points to use [Shokri et al 2010]. OD matrices are essential for various analyses in the field of traffic planning, and they are often estimated from link flow observations [Torbjörn et al. 2010]. It can be obtained from a land use survey of each section; gravity model and Micro level.

Fare collection is considered as one of the main factors at a delay time of buses at bus stops [Hafezi and Ismail, 2011c]. There are several different types of fare collection system, such as smart card information system and touch-n-go card. Generally, user information and validation data are stored in the central server, where these data are transferred to the central server asynchronously. Typically, these data include date and time of the validation, status of the transaction (boarding acceptance, boarding refusal, alighting and transfer), card ID, fare type, route ID, route direction, stop ID, bus ID, driver ID, runs ID, and internal database ID [Pelletier et al. 2011].

This study aims to emphasize on developments of public transport information condition and provide information to travelers over the whole Kuala Lumpur road network base because the dynamic traffic flow information, timetables and fares motivate the travelers to influence traveler behavior also motivate them to switch from private car to public transportation mode. The objective of proposed method output is to have multi-modal travel information on the Internet, covering journeys by road and public transport modes and enable the travelers to book long-distance multi-modal journeys on the Internet with the development of internet based

Table 1. Possible levels of analysis for predicting changes in ridership as a result of transit service change

Spatial scale	Data requirements	Transit outputs
Regional forecasting models	Disaggregated geographical zones; Land use data; Household surveys / facility volumes for calibration;	Mode share by OD zones; Transit assignment. Macro-level changes in mode split.
Regional corridor analysis	Waiting time estimates; Corridor travel times; Change in corridor demand (boardings);	Reductions in traveler generalized costs; Corridor elasticity to generalized costs.
Micro level O-D analysis	Representative survey of passenger origins; Transit line access and egress points; Final destination;	O-D level assessment of service change impacts on ridership;

maps to produce benefits like improved traffic safety, consumer cost and time savings.

2. Methodology

To find out the trip generation in the selected case study (Figure 1), the total land use must be calculated. For this purpose, this study tries to study the map of study area provided by the Kuala Lumpur Municipal Council, study on the detailed map of the study area as published by Google maps and conduct site visits to study area in order to find out the trip generation. There are 407 nodes selected in the study area as a zone and all the available links are located among these zones. Total trip attractions and productions in all the sections in the study area for morning peak hours are 52584.

A heuristic is developed to find Travel System Patterns (TSP). The search process is indicated in Figure 2. To introduce the steps easily, the explanation of each step used in the heuristic is presented as follows.

In the next stage, the OD matrix is used to calculate the trip distribution among the nodes. The double constraint gravity model is used (formula 1 to 3) for finding out the number of the travels among the zones.

$$T_{ij}=k_i k_j ((P_i A_j)/f(C_{ij})) \quad (1)$$

$$K_i=(1/(\sum_j K_j A_j)/f(C_{ij})) \quad (2)$$

$$K_j=(1/(\sum_i K_i A_i)/f(C_{ij})) \quad (3)$$

The standard assumption in (dynamic) traffic assignment models is that route choice is solely determined by a (perceived) deterministic travel time [ManWo and Waller, 2012]. Traffic assignment is based on the fact that travellers choose a route to minimize their travel time and on the assumption of equilibrium algorithm no trip-maker can improve travel time by unilaterally shifting to another route and total minimum travel time should be the least. The user-equilibrium model formulation is based on this area-related observation about equilibrium flows and the fact that the travel time on a route is simply a linear sum of travel times on the constituent links. The formulation, which is a nonlinear programming problem, is given from formula 4 to formula 8 [Rahmat, 1994].

$$\min_{x \in X} z(x) = \sum_a \int_a^{x_a} t_a\ (x_a)dx \quad (4)$$

$$\text{Subject to} \sum_k f_k^{rs} = q_{rs} : \forall\, r, s \quad (5)$$

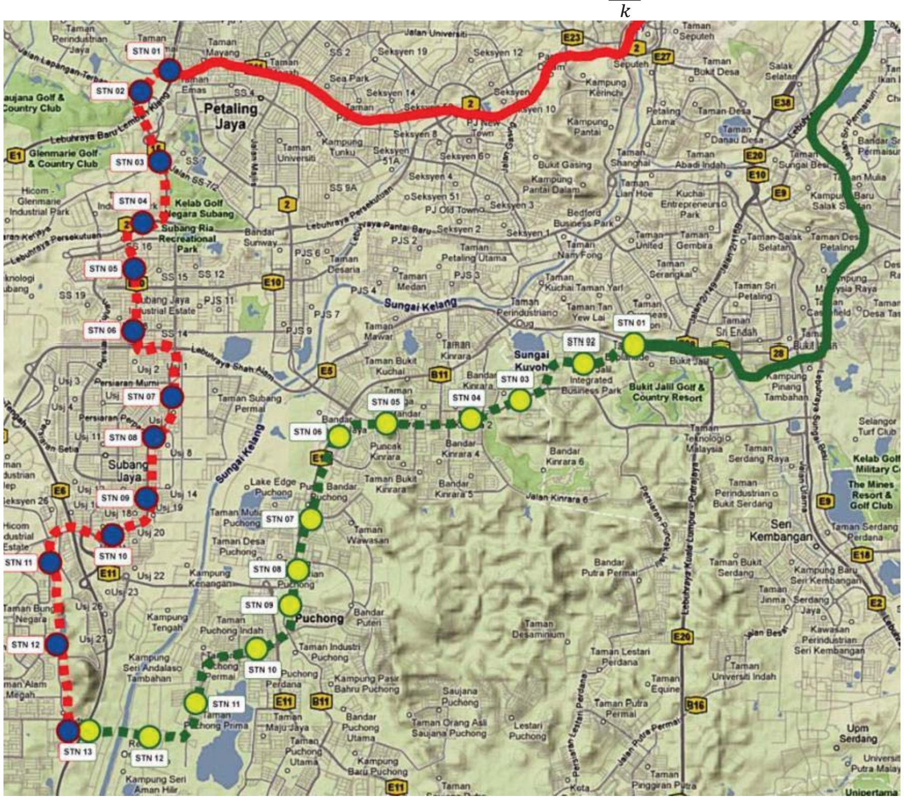

Figure 1. Study area

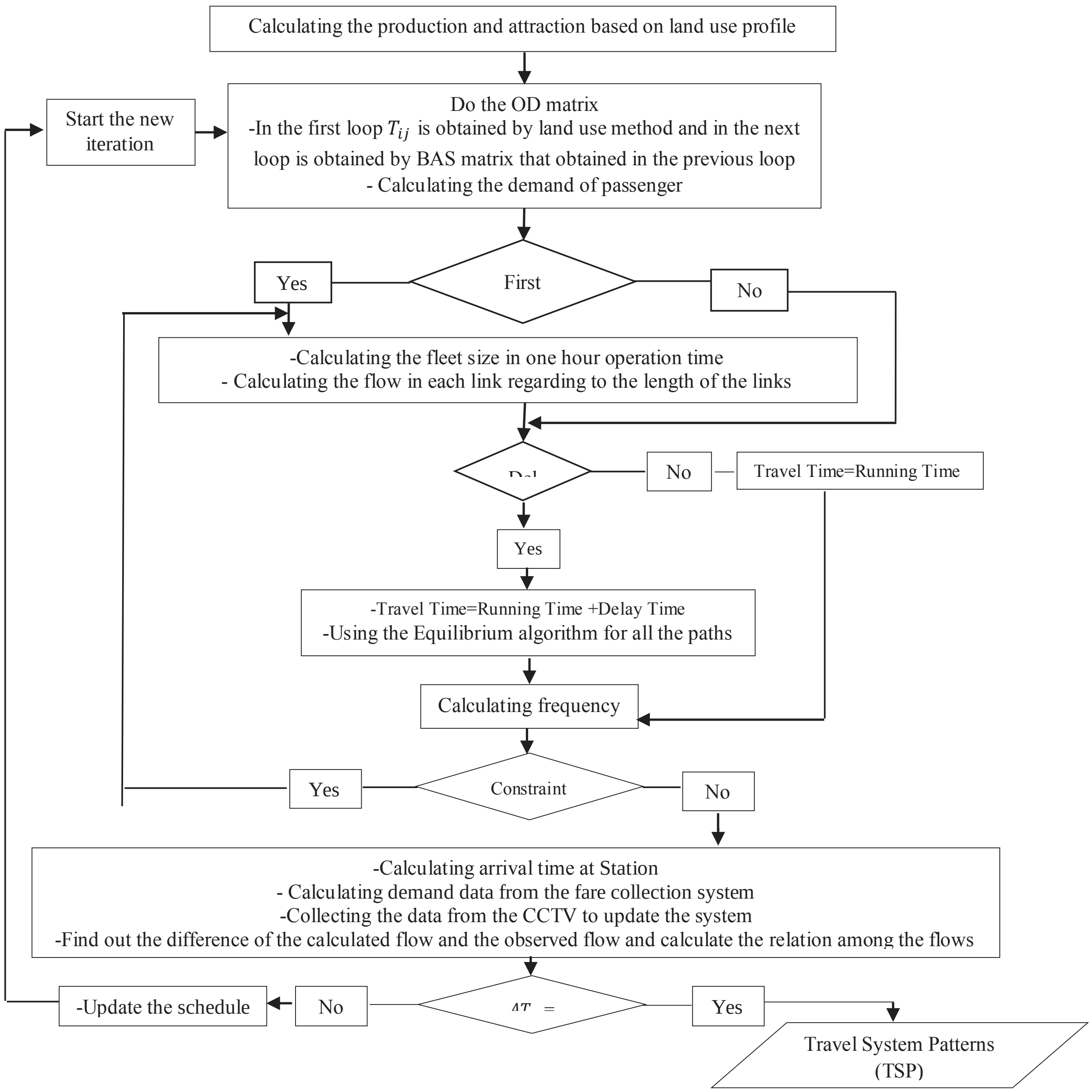

Figure 2. A heuristic of travel system patterns

$$x_a = \sum_r \sum_s \sum_k \delta_{a,k}^{rs} f_k^{rs} : \forall a \quad (6)$$

$$f_k^{rs} \geq 0 : \forall k, r, s \quad (7)$$

$$x_a \geq 0 : a \epsilon A \quad (8)$$

The formula For calculating the total minimum travel time, travel time and the flow value are shown through formula 9 to 11, respectively [Rahmat, 1994].

Total minimum travel time formula:

$$\sum_a \left[m_0 \, v_a + \frac{0.15 * m_0}{c_a^4 * 5} \, v_a^5 \right] \quad (9)$$

The travel time formula is:

$$T°[1+0.15(v/C_1)^4] \quad (10)$$

Flow value:

$$v_a^n = (1-\beta) v_a^{(n-1)} + \beta f_a^n \quad (11)$$

According to operation of buses during different hours in day and week time (weekdays and weekend), average of round-trip time and passengers demand for using the bus have fluctuated. Namely, duration peak-period of traffic travel time is longer than duration of traffic peak-periods. Also, passenger demand for using the bus network duration traffic peak-periods is more than duration of traffic peak-periods. Generally, in a static structure, when two buses depart from the origin terminal at a given interval, they arrive in bus bays at the same interval. But, in actual operation, the situation is different, due to variation in some parameters in the bus schedule, such as average speed, delay time and demand of passengers. The arrival time of buses can be obtained through formula 12:

$$AT_{m,n} = T_{m,n} + d\acute{}_{m,n} + AT_{m,n-1} \quad (12)$$

In the arrival time equation, $T_{m,n}$ is the running time of bus m between two consecutive bus stops. Installed cameras along the section of the roadway send the constant data to the system and monitoring the roadway. The data are sent to the base station from the installed cameras to the project field office. Speed and volume of the vehicles are obtained from the cameras. In each loop, when the data are observed by the cameras, the flow of all the links is calculated by the logic relation among the zones. The coefficient (formula 13) will multiply to the previous attraction and production of the area of the camera to find out the new production and attraction.

Coefficient = (Calculated flow)/(Observed Flow) (13)

3. Delay time of the intersection and roundabout

The control delay of a through movement is the suitable delay used in an urban street evaluation. The delay time of the intersection is calculated by using formulas 14 with online collected data from the CCTV which are given in the highway capacity manual (2000) as follows:

$$d = d_1 PF + d_2 \quad (14)$$

$$d_1 = 0.5C[1-g/C_2]^2 / \{1-(g/C)[Min(1,X)]\} \quad (15)$$

Equation 15 estimates the incremental delay due to non-uniform arrivals and individual cycle failures (i.e., random delay) as well as the delay caused by sustained periods of oversaturation (i.e., oversaturation delay). Formula 16 and 17 shows the incremental delay and uniform delay progression adjustment factor respectively.

$$d_2 = 900T\{(X-1) + [(x-1)^2 + 8kIX/c_3T]^{0.5}\} \quad (16)$$

$$PF=((1-P)f_p)/(1-(g/C)) \quad (17)$$

Roundabout delay time calculation is another part of the delay time that the vehicles face in travelling. Formula 18 shows the roundabout delay calculation formula [Austroads 1993].

$$W_m = W_h + 900T\left[Z + \sqrt{Z^2 + \frac{MX}{CT}}\right] \quad (18)$$

$d'_{m,n}$ is the total of delay time in each bus stop along the bus route. This includes time for boarding, alighting passengers in each bus stop and delay time of the total intersections between two consecutive bus stops which it calculated as a delay time formula. Delay time is equivalent to the maximum value of boarding passenger time and alighting passenger time. Delay time of the bus m at bus stop n can be obtained through the following formula:

$$\acute{d}_{m,n} = max\left[(\alpha.\sum_{n=1}^{j} B_{m,n})\Big/c\,,(\beta.\sum_{n=1}^{j} A_{m,n})\Big/c\right] + \sum d_{m,n} \quad (19)$$

4. Travel System Pattern

The predicting Travel System Pattern (TSP) tries to let the travellers and authority know about the best travel route by considering the shortest dynamic travel time information. For this purpose the travellers are able to know the travel time and other details of the travel route via the internet or SMS system. TSP contains adjustment tools that help the traveler to choose a travel mode. Furthermore, Travel System Pattern is a downloadable file that the traveller is able to download from the internet and install it on the computer or an electronic navigation device such as smart phone, as shown in Figure 3. TSP is automatically connected to the traffic center and is updated through that.

5. Traffic Volume Validation

This study utilises the T test, F test; Chi Square test and regression model to validate the program. There are 93 different routes between the origin and destinations that are chosen. The travel time is calculated in the real situation and estimated by the system. Figure 4 shows a positive straight relation between the travel times, estimated by driving and travel time estimated by travel time estimation system (R^2=0.926).

The mean values (variance) for the two sets of travel times (real and travel time estimation –TSP - system) are 6.95 and 6.65, respectively (Table 2). The result of the test shows that the F test, T test and chi squared test are 414.4634, 1.13 and 12.70052.

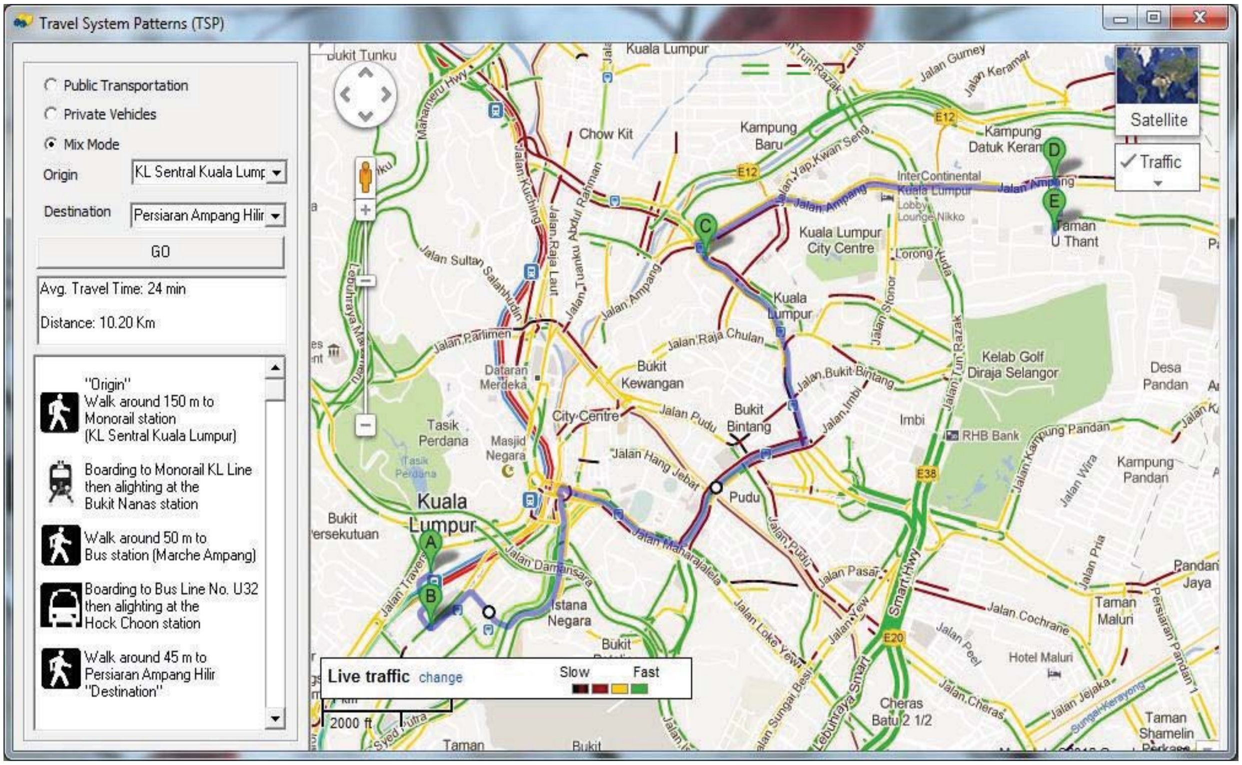

Figure 3. Travel System Pattern

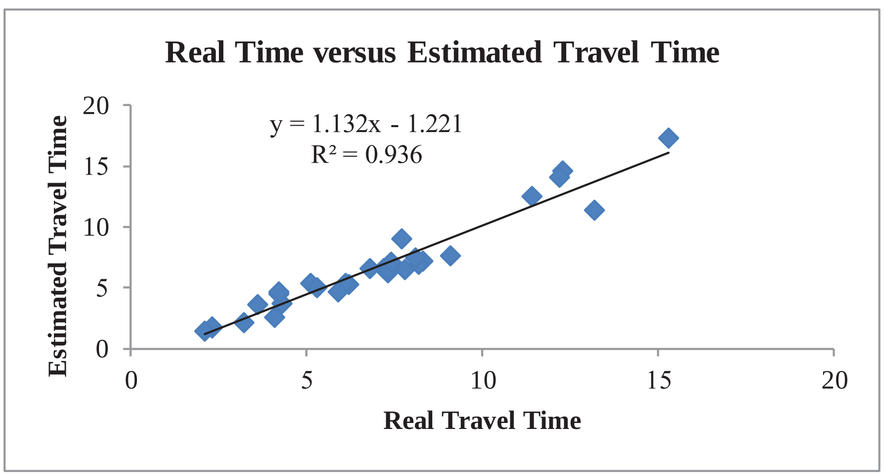

Figure 4. Comparison of the real travel time with the estimated travel time

Table 2. Test of null hypothesis

	Real Travel Time	Estimated Travel time
Size	93	93
Mean	6.95	6.65
Standard deviation	3.35	3.92
R squared	0.926118	
F test	414.4634	
Coefficient of T test	1.13	
Chi square test	12.70052	

6. Discussion and Conclusion

Nowadays, one of the most concerns of travellers is traffic congestion and route assignment. Although there are some other methods that try to find out the best travelling route, most of them are unable to find out all the possible weights of the routes among the origin and destination, in dynamic traffic condition.

Prediction of the dynamic private and public transport trip flow is significant and vital in Transport Demand Management (TDM). This paper proposes a dynamic multi modal mode choice decision to motivate the users to shift from private to public transport system by providing the reliable schedule for different mode of transportation. Furthermore, this study presented an improved formulation and a solution approach for a delay time of intersection and roundabout by dynamic demand. CCTV cameras are used in the system to collect the number of the vehicles and use it as an input for the system that has some potentials such as direct measurement of speed, no need for pavement cut, provide basic traffic parameters (e.g., volume, presence, occupancy, speed, headway and gap), multiple lane operation available, clarity of the image that are captured and recording and saving the data as a historical data.

There are some weakness points for CCTV such as the higher initial cost per camera and reduced ability to cope with low light and high contrast scenes. On the other hand the CCTV camera data are collected and saved in the database and used when the CCTV cameras make an error. Two different types of error from the CCTV are as follows . In the first case, if the number of the vehicles falls to 10% of the previous observation of the camera, it assumes that the traffic jam happens and the vehicles are stuck in the streets and the system gives the maximum time of the travelling. Another frequent error that occurs in the system is the failure of the cameras, regarding to the storage of the data if the observation of the camera becomes zero for two interval loops, the system assumes that the camera is failed and the system uses the historical data and by the first observation of the camera, the system goes to the normal mode.

Based on validation of the study, travel time estimation by the system is more reliable than estimated from the historical data like the Google or other databases. The system is capable of informing the travel time information to the users, before and on the trip, by the internet. The accuracy of the result of validation shows that the travel time estimation system is capable of being used by users and help users to find their destination.

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