Observation of Traffic State Based on Mac Address Matching by Using Bluetooth

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Abstract: Observation of traffic state is crucial to manage traffic in a city effectively. However, it is rather difficult to observe traffic state without installing a large number of traffic detectors. Thus, in this study, the method observed traffic state by using Bluetooth detectors installed on the police boxes at main intersections in the downtown area of Bangkok was proposed. By detecting Mac addresses of Bluetooth devices such as mobile phones by Bluetooth detectors and matching them, the driving routes of vehicles were identified. By accumulating estimated driving route by applying proposed method, traffic state such as origin-destination, congestion road sections, etc. was observed and characteristics of driving behavior in Bangkok was analyzed.

Keywords: Bluetooth Technology, Traffic Data, Observed Pattern Route, Spatial Map

1.INTRODUCTION

To alleviate traffic congestion in a developing megacity, it is quite necessary to control traffic effectively based on traffic state collected through detectors in a city area. However, huge budget and time are required to install a large number of detectors so that it is quite heard to develop such observation system of traffic state in a developing city. Thus, many ideas to observe traffic state by using mobile equipment were proposed and some of them has been put into the market recently. One of such new trial is floating car system, but reliability of floating data is not feasible.

Thus, traffic data collection by a Bluetooth Technology has been applied recently. This technology appears to be an obvious methodology for non-intrusive traffic detection and estimation. There are many study and tests as late as 2010 to investigate traffic state by using Bluetooth as an option. The data from Bluetooth technology provide an information needed as traffic state, density, and flows. It could investigate travel time or speed by matching MAC address of Bluetooth devices where passing through Bluetooth detectors (Malinovskiy *et al.* 2010; Vo, 2011). Currently, Bluetooth device has increasing in our daily life equipment such as smartphone, car audio, speaker, Bluetooth headset, or another gadget.

Then on this study aim to observed and characteristics of driving behavior by accumulating estimated driving pattern route and estimated missing station by using historical travel time. Next, the procedure of this paper will be explaining. Then, the illustrations of pattern trip density are described as spatial map, and concept of using historical travel time is carried out. The final section presents some conclusions recommendation, discussion and ongoing working direction.

2. LITERATURE REVIEW

In recently years, there are several studies related to Bluetooth technology for collecting O-D data. Carpenter *et al.* (2012) used 14 Bluetooth detectors to capture data from vehicle traveling through the SR-23 corridor in Jacksonville, Florida. This work shown that it is possible to use Bluetooth MAC data for O-D studies. The Bluetooth detector can be make more advantage than a traditional O-D matrix, which it could provide information about the specific route traveling for detected MAC address of a vehicle. Filgueiras *et al.* (2012) has deploy five point of Bluetooth station at a key entry point of the urban area of the city of Porto, Portugal. Where able to measure the amount of time that people stayed in the city. This result confirmed that Bluetooth sensing technology could be setup with promising result. Blogg *et al*. (2010) collecting O-D data by observations of Bluetooth protocol devices embedded in vehicles and motorist mobile devices to collected the O-D data. They found that collecting and extension methodology could be improved. Also, Hainen *et al.* (2011) Using Bluetooth to evaluated the impact of an unexpected bridge closure in north west Indiana, this observed travel times were also compared with travel time estimates obtained by route classification and link distance. They found that the route choice behavior was relied on travel time estimates. They also recommended the Bluetooth technology provided a much more cost effective mechanism for capturing route choice information than traditional license plate matching technologies. And they also use Bluetooth MAC address matching for capturing route choice information as well. Hainen *et al.* (2011) also estimated the distribution of traffic on the flow of alternative route, they found that 54.7% of traveler selected the local route. Those studies show that Bluetooth Technology were using to collect only O-D data, but cannot recognize route pattern on each Bluetooth MAC address.

Penetration rate is a proportion of matching rate per traffic volume on each link. A good rule of thumb is for the number to be at least three matched pairs every five minutes, or nine matched pairs per 15 minutes, 36 matched pairs an hour, or 864 per day (KMJ Consulting, 2010). Other authors were obtained penetration rate as, Wieck (2011) recieved matching rate varied from 3% to 11.4%, Steel and Kiburn (2011) installed 30 units on a highway ring road for one week and got path varied from 6.5% to 9.4% with an average of 7.4 percent, KMJ Consulting *et al* (2010) had a match rate of 3.5-4.1%. For penetration rate on our study, traffic comparison on each link was obtained data from Traffic and Transport Department Bangkok in 2015 and traffic volume from Bluetooth detector is average from 29 days start from 07:00 AM to 07:00 PM. The penetration rate around 3-5% in all link, this sample given adequate fleet size.

In practical, it is not possible to capture all MAC address that passing through the Bluetooth scanner. Puckett and *et al.* (2010) suggested that an optimal positioning of the antenna was at the windshield height of a typical passenger car. Stevanovic *et al.* (2011) also found that it is harder to detect devices that are in the pocket of the passenger compared to devices that sit on the vehicle's dashboard when the antenna is on top of a traffic cabinet. Thus, the position of Bluetooth devices on vehicle or some obstruction in the car's body that might be interrupted Bluetooth signal.Brennan *et al.* (2010) suggested that the antennas should be installed at least 2.5 meters above ground between the carriageways (or on the side of the road if only one carriageway) with no obstructions between the antenna and the traffic.

Thus, to make a complete trip, some missing section of route path will be conduct by estimation technique, we use the historical travel time for estimating missing station. It is primary concept to find missing station on trip. In addition, missed detections are several situations. Michau G. *et al*. (2016) found that missed detections made the retrieval of travel pattern even more challenging. They propose three algorithms to solve this problem, the first one for separation trip information, consisting of fixed the origin, destination and using intermediate detections for each detected device, the second one for proposing trajectories out of the recovered trip information and the third one for discriminating type of traveler by separating motorized from non-motorized modes of travel. They also have illustrated its efficiency: tested on two case studies, the result found that trajectories were at 84% corresponding to the ground truth. Hence, in this paper we are interested in finding complete pattern trip from missing detections of trip, by using historical travel time.

3. EXPERIMENTAL METHODOLOGY

Processes to analyze a traffic route patterns in Bangkok by using Bluetooth technology were described in this section. In part of data collection, Bluetooth detector have been deployed forty-one locations along CBD area of Bangkok for provide traffic state such as origin-destination, congestion on road sections, etc. Bluetooth devices were installed in police boxes at intersection along main road such as Rama VI Rd., Phayathai Rd., Phetchaburi Rd., Sukhumvit Rd., Rama I Rd., Rama VI, and Sathon Rd. The devices are working all 24 hours, start from 5th February to 4th March 2016. The locations of Bluetooth detector are shown as a figure 1.

Figure 1. Bluetooth detector deployment location

In this section describe the procedure for obtaining a trip. Trip is a route pattern of one unique MAC address which detected from origin point (start station) to destination point (end of station). The procedure for getting trip are shown in figure 2.

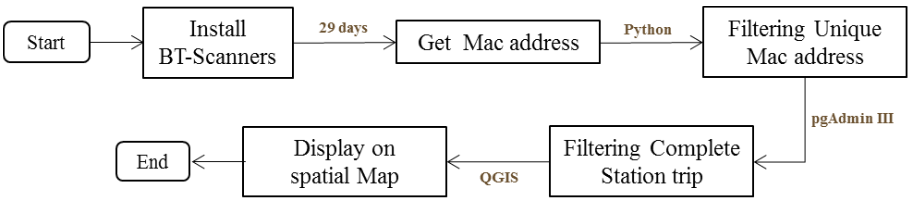


Figure 2. Illustration of procedure for obtain a trip

Data from Bluetooth detector were exported from database server as a raw data which including 235,316 MAC address. The criteria for split trips is consider both of velocity and travel time. On this study, we use the lowest speed is 2 km/hr and travel time more than 30 mins for split each trip. Same as Carpenter *et al.* (2012) has testing parameters ranging for generated trip-linking by Bluetooth detector ranging from 5 to 60 min, 30 min was chosen as it is the most reasonable for the corridor which have a maximum distance between adjacent sensor pairs was 1-5 mile. In basically, the longer this time criteria for split trips, the longer the average trip itinerary will become using more Bluetooth detectors on a single trip, which results in fewer total trips. Hence, on this study 30 min was chosen based on the travel time. Sample of trips that split of these criteria are shown in figure 3

order	BT. MAC address	Time	BT. Station	Time diff.	Speed (km/hr)
1	38:C0:96:76:BD:C0	21:29:01	48	0:03:51	11.22
2	38:C0:96:76:BD:C0	21:32:52	26	0:00:31	37.51
3	38:C0:96:76:BD:C0	21:33:23	33	-	-
4	38:C0:96:76:BD:D5	21:22:36	38	0:03:18	21.69
5	38:C0:96:76:BD:D5	21:25:54	12	0:12:46	2.66
6	38:C0:96:76:BD:D5	21:38:40	49	0:05:07	12.30
7	38:C0:96:76:BD:D5	21:43:47	35	0:01:45	5.11
8	38:C0:96:76:BD:D5	21:45:32	42	1:16:18	0.13
9	38:C0:96:76:BD:D5	23:01:50	35	0:01:31	6.73
10	38:C0:96:76:BD:D5	23:03:21	42	-	-

Trip 1 (orders 1–3)
Trip 2 (orders 4–8)
Trip 3 (orders 9–10)

Trip 1 & Trip 2:
Split by MAC address, it is different.

Trip 2 & Trip 3:
Split by Time Interval or speed (not more than 30 mins or lower than 2 km/hr.

Figure 3. Sample of trips that split by time and speed criteria

Thus, from all MAC address (235,316 MAC) change to total trip as 1,398,329 trips. However, these trips including “Complete trip” and “Missing trip”. Complete trip is the trip that connecting continuously station in one trip. The sample of complete trip are shown as figure 4a and 4c. Another trip intermittently that missing some station in one trip was called as missing trip is shown as figure 4b. Nevertheless, the complete trip which consist of single trip, round trip, and two-station trip as figure 4a, 4c and 4d respectively. Only single trip were used for describe driving analysis. For round trip and two-station trip were removed from data set due to it could be motorcycle taxi or pedestrian, which cannot analysis as well.

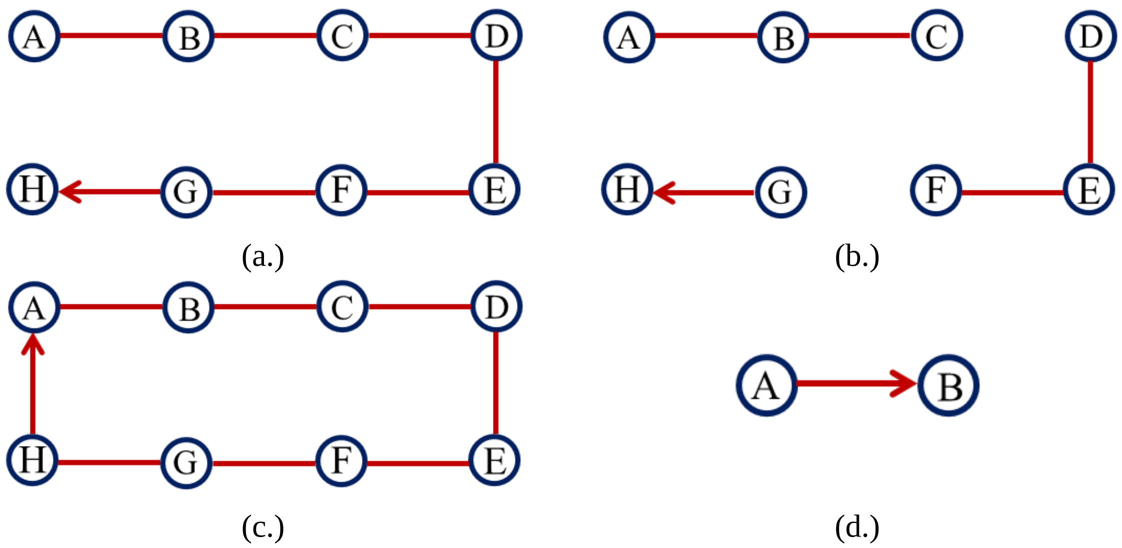


Figure 4. Types of trip from results; (a.) complete trip, (b.) missing trip, (c.) round trip, (d.) two-station-trip

On table 1 are shown details of each type of trip, after filtering raw data of MAC address we obtained around 1,400,000 trips from unique MAC address, including complete trip around 610,000 trips (44%), missing trip 780,000 trips (56%). Hence, the finally complete trip after cut outliner amount of 173,900 trips was analyzed.

Table 1. Type of trip on the study

No.	Type of Trip	Amount (trips)	Details
1.	All trip	1,398,329	Unique Mac address
2.	Complete trip	612,056	Before cutting outliner
3.	Missing trip	786,273	-
4.	Complete trip (final)	173,900	After cut round trip and two-station-trip

On a figure 5 is shown the connected trips continuously, the highest portion of continuous station per trip is 3 stations with 107,095 trips (61%) and the maximum of continuous station per trip is 14 stations with 2 trips. Thus, most of trips (61%) are quite short trip.

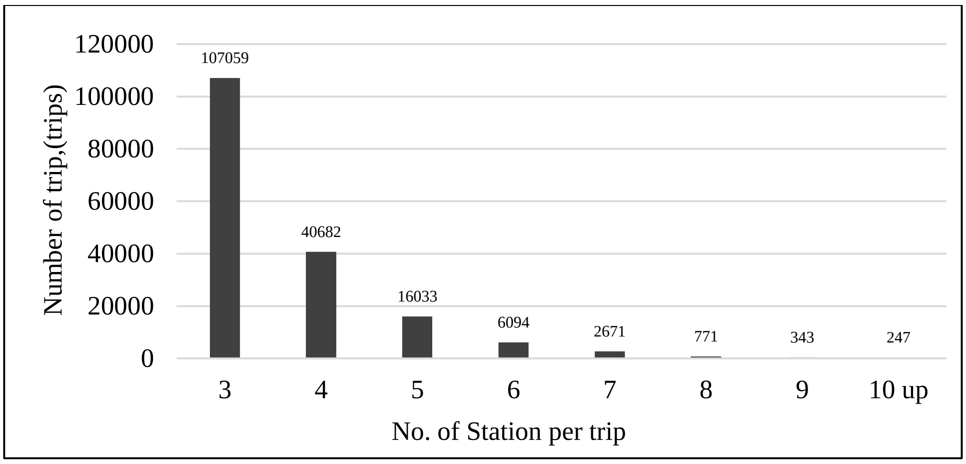


Figure 5. Number of connected station per trip

5. RESULTS

5.1 Observe and route choice behavior

After cut round trip and two-station-trip, the complete trips were display on spatial map format to understand overview of traffic pattern and density on each link. On figure 6 is shown pattern and density of accumulate trips, most of trip pattern density occurred on link 30-25, 52-27, 29-12, and 37-33 along main road in the downtown area of Bangkok. Trip pattern of week-day and week-end were identical as show in figure 7, while density was decreased on week-end cause of volume from working trip is disappear. Time duration also an effect to trip pattern density format, on morning peak the density of trip is higher than evening peak, both of week-day and week-end.

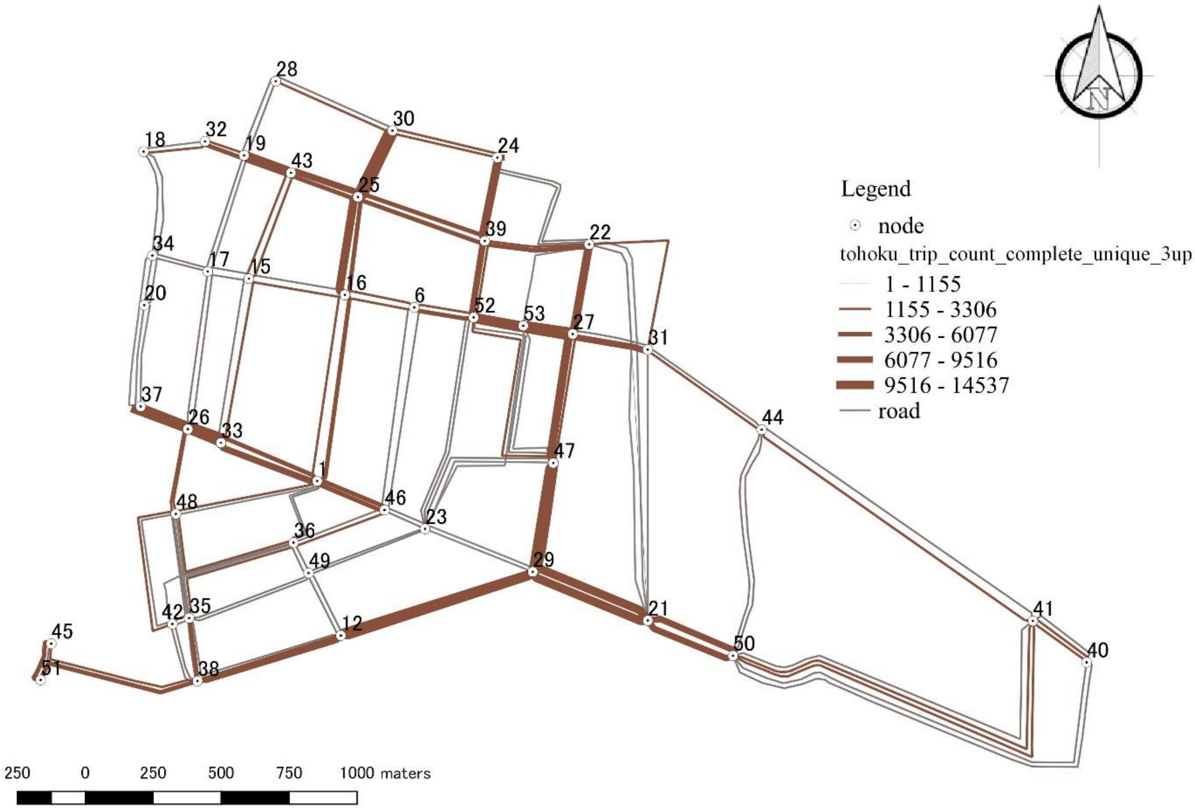


Figure 6. Illustration of complete trip pattern

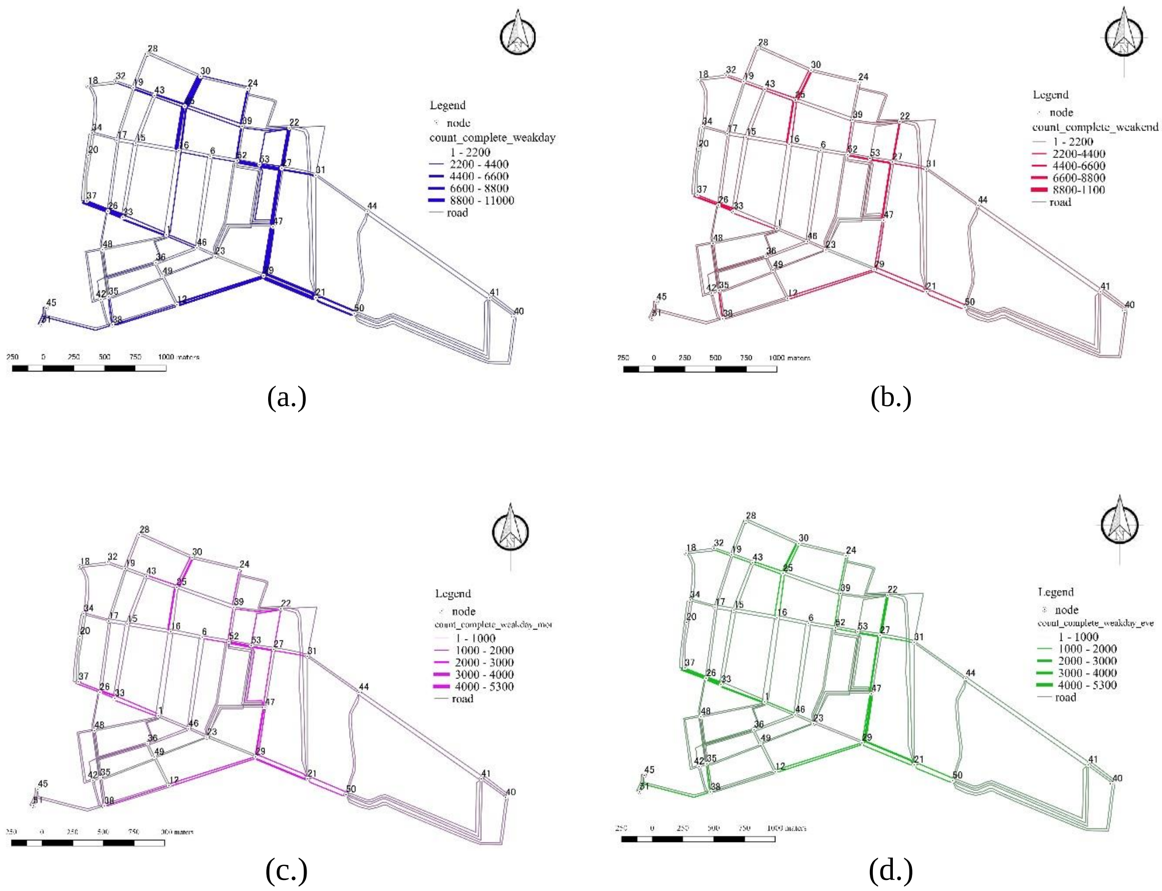
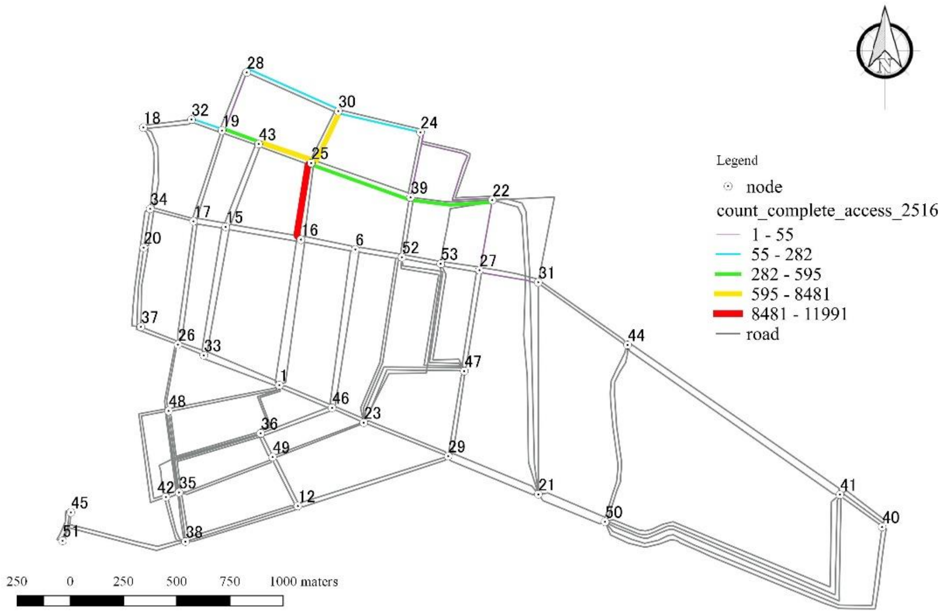
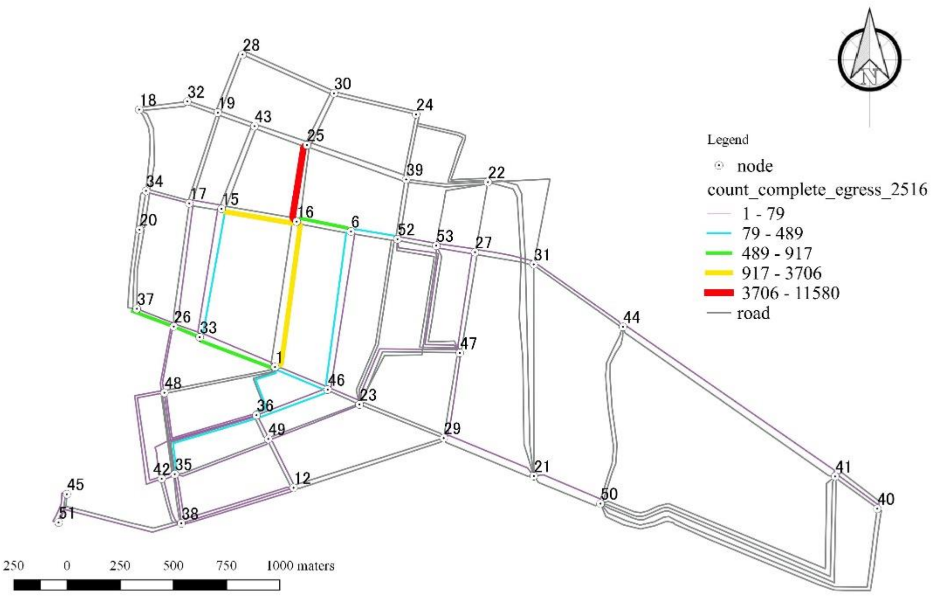


Figure 7. Illustration of trip pattern consist of; (a.) weak-day trip, (b.) weak-end trip, (c.) weak-day morning peak trip, (d.) weak-day evening peak trip

Characteristics of pattern trip behavior was analyzed through specific route choice behavior. For understanding, we collected the specify target link for analyze origin and destination path pass-through target link, which link 25-16 and link 47-29 were selected as target link. Spatial map on figure 8a is shown the density of pattern trip access through link 25-16 represent by colors, the red represented a highest density followed by yellow, green, light blue, and pink represented a lowest density of pattern trip. Most of trip came from link 30-25 and link 43-25 have access to target link 25-16, while on figure 8b is shown the density of pattern trip have egress from link 25-16. We found that, most of trip egress to link 16-15 and 16-1. For origin and destination path pass through link 47-29 were shown are figure 9a and 9b, most of trip have access to link 47-29 is came from link 53-47 and link 27-47, while most of trip egress from link 47-29 through link 29-12 and 29-21 represented by figure 9b. These result is an information to understand route choice on each area.

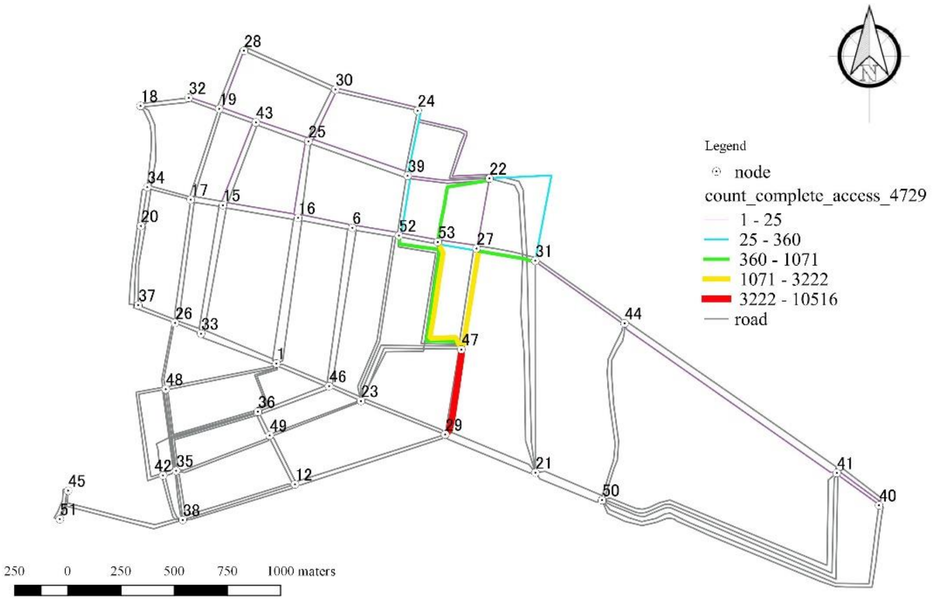


(a.)

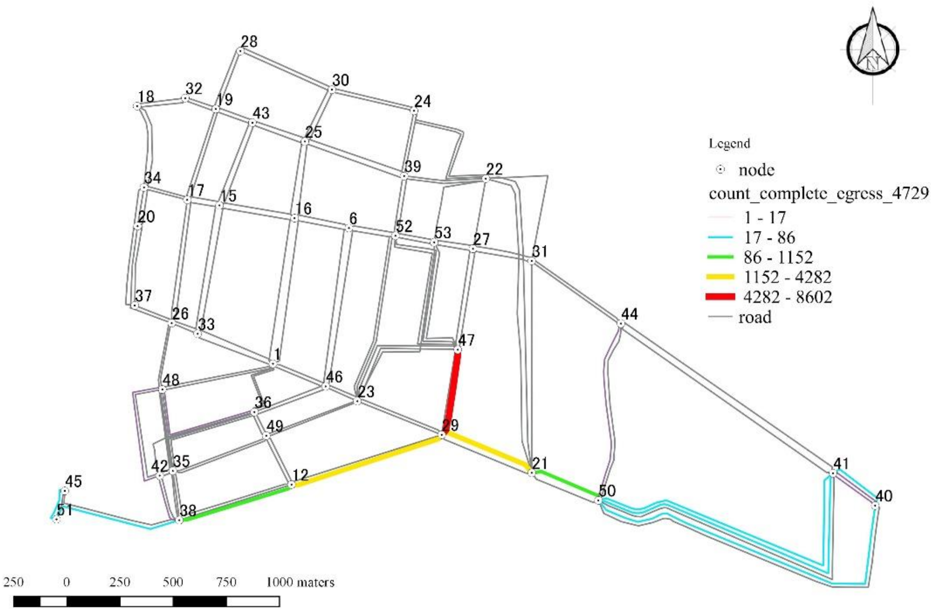


(b.)

Figure 8. Illustration of Target Pattern Trip on link 25-16; (a.)Trip access-through link 25-16, (b.)Trip egress from link 25-16



(a.)



(b.)

Figure 9. Illustration of Target Pattern Trip on link 47-29; (a.)Trip access through link 47-29, (b.)Trip egress from link 47-29

This section will be described the example of same route on one month of individual mac address. From table 2 is shown results of example individual mac address on one month in the same route. On example, we found that, driver chose the route same pattern like commuter driver is shown in figure 10 and 11. Figure 10 also shown route choice of mac address 74:5E:1C:65:9x:xx, usually it was chosen route 30-25-6, and some time other route. And figure 11, we found that mac address A8:1B:5A:B4:2x:xx was chosen different some path of trip for morning trip and evening trip, in morning path 15-43-30 (red) has been chosen from driver and in evening path 30-25-16-15 (blue) has been chosen. These results can be shown specific route pattern behavior of travelers, we found that most of trip occurred on the main road, while the accumulating travel time from this study are shown that some of local route can be spent time to travel less than main route. The characteristic of route choice behavior from drivers might be not choose the best route due to their lacking in traffic trajectories information.

Table 2 The same route on one month of individual mac address

Mac Address	**One month**			
	Same route		**Other**	
	trip	**%**	**trip**	**%**
4:5E:1C:65:9x:xx	61	82	14	18
8:1B:5A:B4:2x:xx	29	94	2	6

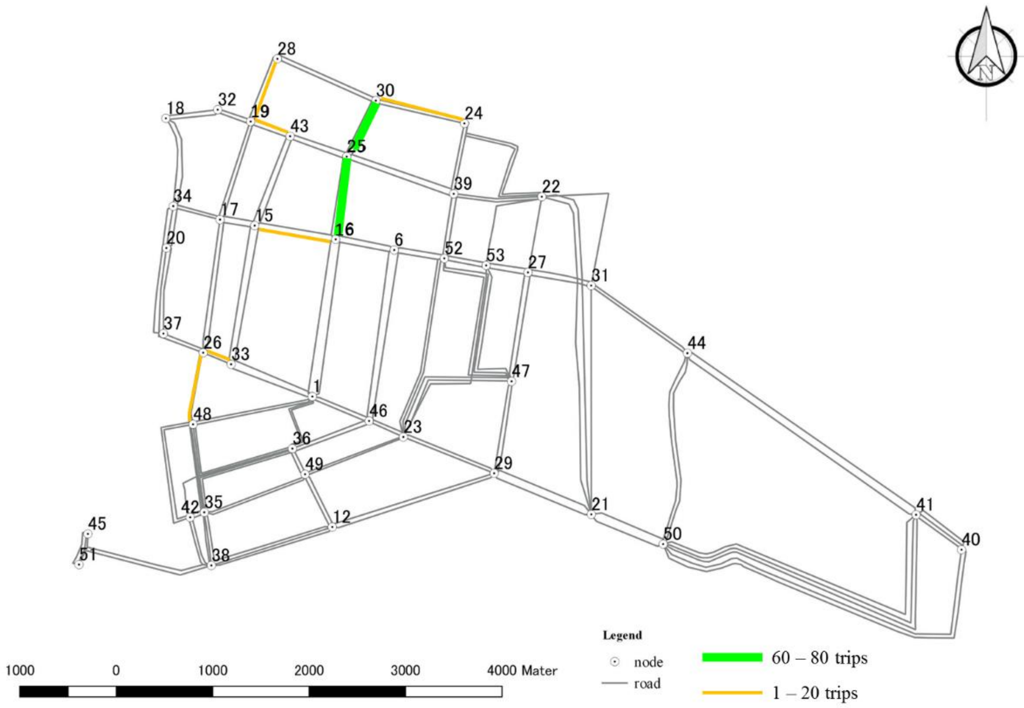


Figure 10, Illustration route choice on 29 days of Mac address 74:5E:1C:65:9x:xx

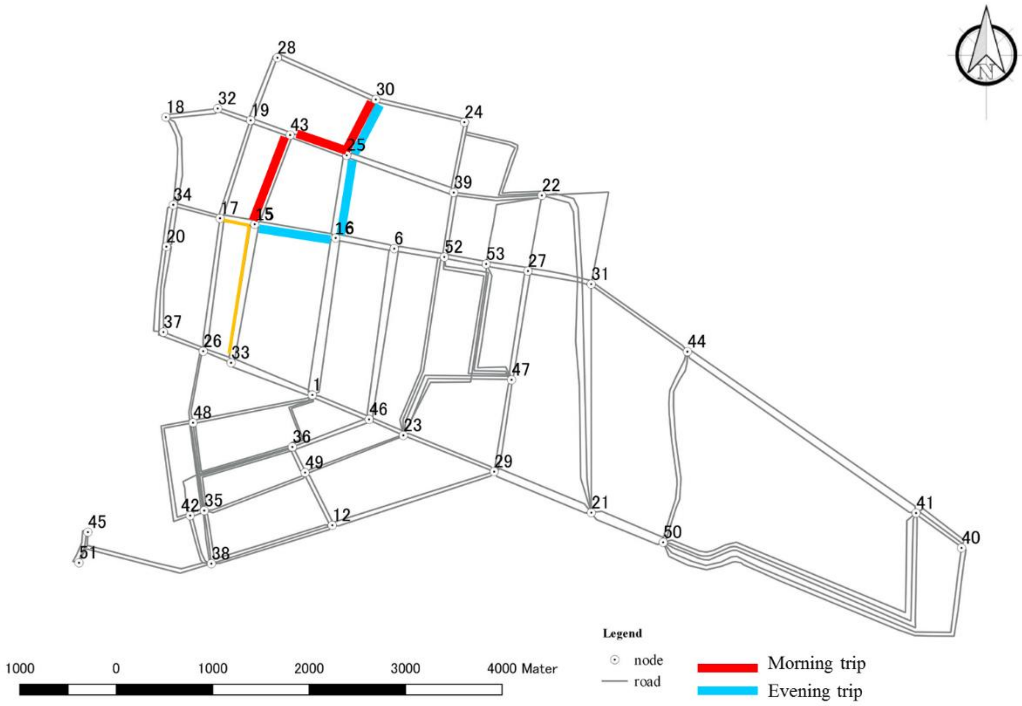


Figure 10, Illustration route choice on 29 days of Mac address A8:1B:5A:B4:2x:xx

6. CONCLUSIONS

On this study aim to observe and characteristics of driving behavior by accumulating estimated driving pattern route and estimated missing station by using historical travel time.

The observation, only complete trip was using for investigate route pattern due to missing trip cannot represent traffic route patterns or demand on each link. For complete trip that have been used is 173,900 trips which this data is enough to represent traffic route pattern on spatial map. This result is an information to understand route choice on each area. Normally, characteristics of travel behavior are choosing the simple route; main road, familiar route pattern. While they may do not worry about traffic congestion or spend a lot of time on the road. Thus, the perfectly traffic information will be guild and encourage suitable route choice for traveler, exactly driving behavior can be change.

7. ACKNOWLAGDEMENT

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