An Analysis of Probe Data on Traffic Congestion During the Typhoon Using GIS Application

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Abstract: Traffic congestion analysis is one of the most important issues for capacity development and betterment of traffic flow. In this research, the data on taxi probe car facilitated with GPS system was used for analysis of the effects of typhoon Roke focusing especially for the commuters' homebound trips. The results showed that, the congestion was very severe as the rate of congestion increased, at most, by up to 4 times more than usual. In this study, we analyze and compare the results from probe data and one's questionnaire survey. We explored the advantages and disadvantages of both methods. The most congested sections and their severity are presented accordingly. The outcome of this research will help policy makers to find best solution for alleviating severity of congestion in case of any further emergency happened.

Key words: Traffic Congestion, GPS-GIS Integration, Typhoon, Homebound Commuter

1. INTRODUCTION

Every year typhoons are the most frequent disaster for Japan. On 20th September, 2011 Japan has experienced the devastating typhoon Roke and faced severe traffic congestion in and around big cities like Nagoya. The coastal cities with bays such as Nagoya, Toyota, Ise, etc. are the most prone to marine calamity. This calamity came to broad daylight on day of typhoon Roke. Over a million people, more than double the numbers for previous typhoon, living in Nagoya were also forced to evacuate (Wikipedia, typhoon Roke).

Several companies eliminated the evening shift due to the typhoon. Commuter trains were halted and thousands of passengers were stranded though they tried to go home early before the storm hit. This left no other choice for the commuters' to get back home other than using the roadway and resulted in severe traffic congestion. The typhoon also caused heavy rainfall, flash floods, landslides and high waves which introduced brimming of local rivers and some bridges and roads were shut down. Therefore, only a few routes were available for the traffic, and this added another dimension to the congestion severity.

It is understandable that, congestion is an unavoidable traffic event but unto some degree. Traffic congestion is not welcomed at any road section especially in the emergency situation when each and every second is more valuable than usual. This is the challenge to balance the traffic volume and the available capacity to alleviate the severity; especially, when it took place at the time of disaster or in any case of emergency evacuation. However, the constraints of emergency situation are not deliberated solely while designing any roadway section.

Considering that, this research tries to achieve a better understanding about the degree of congestion which was faced on the day of typhoon. This information is very much necessary for transport planners to assess the bottleneck and to manage traffic in any case of emergency. In addition, we use GPS data for analysis in order to incorporate the most advanced and intelligent way of data collection system. Moreover, together with the GPS data, GIS application was used to give the analytic results on the actual situation and to operate link or section based examination. Therefore, in this study, we utilized taxi probe data in which a probe car facilitated with Global Positioning System (GPS), which collects information on position, speed, vehicle status and direction of travel, was used on a day of typhoon for analysis of the impact to commuters'. In this modern age, conventional database systems are not used because of their drawbacks and are replaced by GPS based data recording tool for its spatial integration such as latitude and longitude with other relevant databases of that region. In both planning and design and in real-time monitoring of traffic systems, GIS techniques can be applied. The use of Global Positioning System (GPS) data to determine locations by the data of latitude and longitude, for both static and dynamic recording of vehicle positions over time is the basic constituent of the GIS based system. In terms of data entry and integration, data management, and few features of data analysis and display GIS takes on the central role in data management. The capabilities of GPS as a tool in moving observer traffic studies was introduced by Quiroga and Bullock, (1998a). Where, moving car or moving observer method of traffic stream measurement has been developed to provide simultaneous measurement of traffic stream variables.

In recent research, there are many studies on pre-disaster evacuation and post-disaster network reconstruction. However, there are only a few studies focused on the situation during disaster, which is more crucial in the case of typhoon. Studies during downpour conditions, such as Fujita *et al*. (2011), analyzed individual behavior and awareness of disaster prevention among public transport users for the future downpour through a questionnaire survey. However, the study does not contain any analytic approach specifically on travel time escalation. This study, therefore, tries to overcome the problem through the intelligent way of Geodetic technology. In the work of Fujita *et al.* (2011), they showed that, about 53% of homebound commuters' attempted to leave work early with intention to avoid the typhoon but instead they have congestion. Zito *et al*. (1995) showed that, usefulness of probe data for traffic studies in an intelligent way along with GIS software. Taylor *et al*. (2000) described the application of GIS software to the analysis of travel time, delay and congestion of urban road corridors using probe data. He also discussed the nature of traffic congestion, in a broad definition and the discussion of a number of parametric measures of congestion. Quiroga and Bullock (1998a) provided a key example of the capabilities of GPS as an important tool.

Tomio *et al*. (2004) stated that, GPS data collection is a price effective and precise option for data collection. They developed a method for identifying the vehicles' cruising routes whether or not they are on elevated expressways and also when the intervals of data transmission are comparatively long. Tomio *et al.* (2004) also developed a travel time prediction model applying the link cost table estimated for Nagoya Metropolitan Area.

Zito *et al.* (1995), Taylor *et al.* (2000), Quiroga and Bullock (1998a) and Tomio *et al*. (2004) inspired us of choosing GPS-GIS integration method of analysis with the data recorded by moving observer. However, this type of study is very rare in an emergency situation, such as on the eve of typhoon, when we need to have a better and clear understanding about the situation. Nobuhiro *et al.* (2009) discussed the application of bus probe data to evaluate travel time variablility. They also mentioned the importance of further data transformations such as map-matching, data reduction, processing, and reporting to make them meaningful to any transport analysis. Liang *et al.* (2005) used a taxi as a probe vehicle to present a model designed to provide arterial speed estimation. They validated the usage of taxi as probe vehicle for transportation factor analysis with an excellent level of precision. Liang *et al.* (2005) and Edward *et al.* (2003) proposed a method for data reduction for OD trip generated by taxi probe cars. Many researches attempted to assess the impact of disaster to traffic through questionnaire survey, such as the work by Oohashi and Fujita (2012). However, Murakami and Wagner (1999) mentioned that, written diary type survey include lack of reporting for short trips, poor data quality on travel start and end times, total trip times and origin-destination locations. Whereas, device with a Global Positioning System (GPS) receiver is capable of collecting vehicle based information such as trip purpose and vehicle occupancy, other data such as date, start time, end time, and vehicle position automatically, in a more precise way at frequent intervals. Despite having some drawbacks, Murakami and Wagner (1999) proposed that, GPS has superiority over any respondent oriented survey for better trip reporting as well as a better level of precision.

In this research, we are using GPS data and plot it on the GIS road network to attain a clear insight to the situation of traffic flow under disasterous condition. This method will assist to explore the bottlenecks to find countermeasure for an improved traffic flow during an emergency situation. In addition, we present a comparative study between the output from a questionnaire survey and the output from probe data, to observe any variety in considerations, to validate the reliabilty of both methods, and to learn the shortcomings to improve further research. As from the infromation of traffic obstruction, it was found that public transport services have been cancelled, leaving commuters' no other choice than using automobile for homebound trip. Consequently, it increases the Taxi trip and the demand rises over capacity and congestion triggered. Precisely, it was tried to visualize and interpret the intensification of travel time for specific OD trips on the day of the typhoon, which was facilitated by the application of GIS in the comparative study.

The rest of the paper is organized as follows. In the next section, the outline and some finding of the questionnaire survey will be discussed. In the third section, the probe data will be introduced and methodology will be described. The output will be explained in the fourth section. Finally, we will conclude with discussion on future directions.

2. QUESTIONNAIRE SURVEY ON TRAVEL TIME DURING TYPHOON

2.1 Typhoon Situation:

The typhoon approached the *Tokai* region during 19th September and 21st September and reaches its peak on 20th September, 2011. It rained heavily in Nagoya city and the surrounding regions.

The maximum hourly precipitation and total precipitation in the *Tokai* region is shown in Table 1. The maximum hourly precipitation by this typhoon was in Okazaki-city which is a part of Aichi prefecture and situated at the south-eastern side and about 35 km far from Nagoya.

Table 1: Precipitation record on the eve of typhoon

Prefecture	Municipality	Point	Maximum hourly precipitation (mm)	Start time (LST, Date)	Total precipitation (mm)
Aichi	*Nagoya*	*Nagoya*	45.5	15:56 20th	274.0
	Toyota	*Agura*	53.5	10:14 21st	383.5
	Toyone	*Chausuyama*	33.0	14:49 21st	367.0
	Okazaki	*Okazaki*	78.0	4:59 20th	231.0
Gifu	*Tajimi*	*Tajimi*	76.0	16:36 20th	496.0
	Yaotsu	*Karan*	54.5	12:09 20th	401.5
Mie	*Tsu*	*Tsu*	36.0	12:41 21st	289.5
	Oodai	*Miyagawa*	52.0	07:43 21st	465.0

2.2 Obstruction to Traffic Flow:

The typhoon was so severe that some parts of expressways were closed for some duration. Table 2 shows the sections of highway and duration what were closed, due to the typhoon. Table 3 contains the detail information on suspension of train service. It can be noted that, suspension situations occurred over large areas of the *Tokai* region.

Table 2: List of Interchanges of Expressways, closed due to typhoon

Name of the Expressway Line	Closed section (from-to)	Start	End
Tokai-Kanjo Expwy	Toyotafujioka IC - Kanimitake IC	09:10 20th	01:00 22th
Chuo Expwy	Ena IC - Komaki IC	12:00 20th	06:30 22th
Mei-Nikan Expwy	Narumi IC - Kamiyashiro JCT	12:30 20th	15:45 20th
Komakihigashi IC Toll Road	Starting point - Ending point	13:45 20th	17:00 21th
Tomei Expwy	Nagoya IC - *Kasugai* IC	17:00 20th	20:30 20th
Shin-Meishin Expwy	Kameyama JCT - Koukatsuchiyama IC	09:00 21th	17:30 21th
Isewangan Expwy	Tobishima IC - Miekawagoe IC	14:00 21th	16:30 21th

Table 3: List of Train services closed due to typhoon.

Name of different Rail route Line		Interval (from-to)	Start	End
JR-central	Tokaido Line	Nagoya - Biwajima	17:25 20th	00:33 21th
JR-central	Chuo Line	Nagoya - Kouzouji	17:22 20th	06:30 21th
JR-central	Taita Line	Minooota - *Tajimi*	17:23 20th	12:00 22th
Nagoya Railroad	*Seto* Line	All	17:25 20th	21:00 20th
Nagoya Railroad	Tokoname Line	Jinguumae - Ooe	17:27 20th	21:00 20th
Nagoya Railroad	Hiromi Line	Inuyama - Mitake	19:11 20th	02:00 21th
Nagoya Railroad	Inuyama Line	Nagoya - Kamiotai	19:13 20th	21:00 20th
Nagoya Railroad	Nagoya Line	Sukaguchi - Toyoake	19:13 20th	21:00 20th
Nagoya Railroad	Komaki Line	Komaki - Kamiiida	19:15 20th	02:00 21th
JR-central	Iida Line	Shinshiro - Tenryuukyou	07:09 21th	First train 23th
Nagoya Railroad	Airport Line	Tokoname - Chubu Airport	07:11 21th	11:38 21th
JR-central	Tokaido Line	Toyohashi - Gamagoori	11:07 21th	16:42 21th
Nagoya Railroad	Nagoya Line	Toyohashi - Shin'anjou	11:07 21th	18:05 21th
JR-central	Tokaido Shinkansen	Tokyo - Nagoya	13:00 21th	First train 22th
Nagoya Railroad	Toyokawa Line	Kou - Toyokawainari	15:40 21th	18:05 21th

2.3 Questionnaire Survey

A questionnaire survey was carried out primarily for those who used automobiles or public transportation or both for homebound trip on the 20th September 2011. Questionnaires were distributed to commuters’ along the JR *tokaido* line or *chuo* line etc. where the train services were interrupted on that day. Figure 1 shows the locations where the questionnaires were distributed. The questionnaire survey was run on the context of homebound commuters’ and emergency evacuated people faced trouble for their trip. Roughly, 634 respondents, 4 days long collection, with an average discovery rate of 12.67%, spreaded among 5 cities and one ward of Nagoya city, received by postal and mail service. The study was not only for public transport but also for automobile users.The inquired information was as follows:

1) Details on the homebound trip in normal situation;
2) Details on the homebound trip on the day of typhoon;
3) Whether or not the person have accessed the information on typhoon;
4) Evacuation situation on the day of typhoon;
5) Awareness of disaster;
6) Personal attributes (sex, age, family structure, etc);

Table 4: A brief outline of survey during typhoon

Place	Day	Method	Distribution number	Sample	Response rate (%)
Ichinomiya-city	2012/02/22 ～ 2012/02/25	Posting & Mail recovery	800	83	10.4
Gifu-city			800	83	10.4
Kasugai-city			800	109	13.6
Tajimi-city			1000	129	12.9
Seto-city			800	113	14.1
Moriyama-ward			800	117	14.6

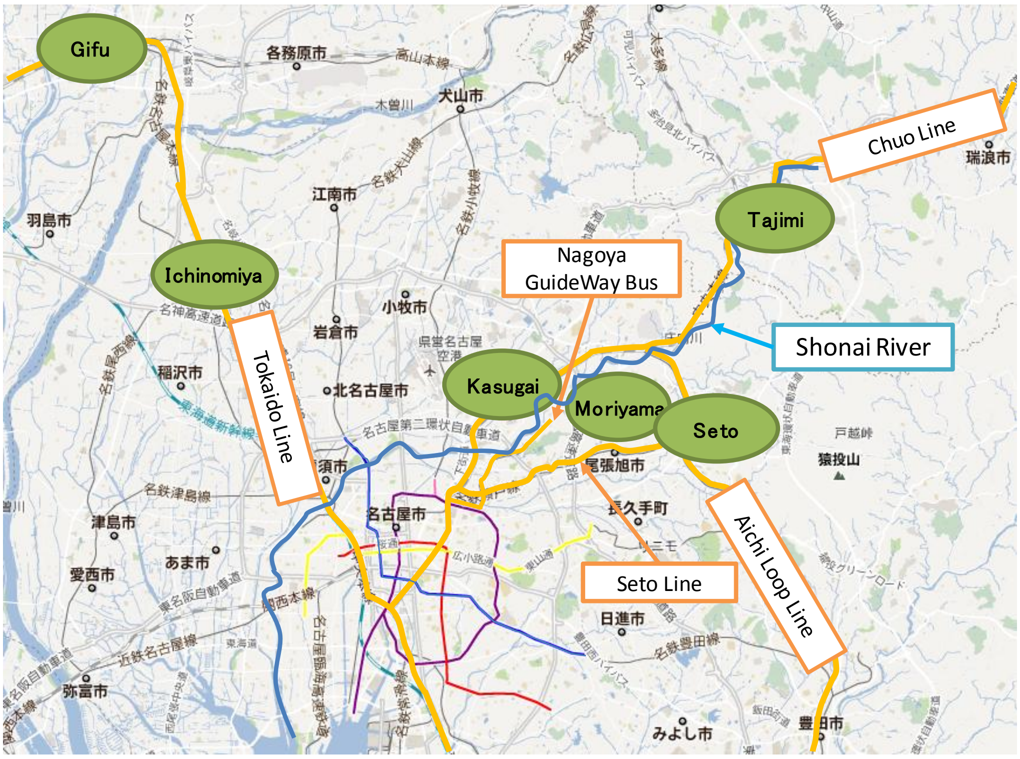


Figure 1: The survey locations

2.4 Some Findings from the Questionnaire Survey

For railway users bound for *Ichinomia* and *Kasugai,* many of them changed to use car (taxi or company car etc.) as their travel mode on the typhoon day. Most of the passengers bound for *Gifu* and *Moriyama* ward used train or bus whichever was available. Half of people traveled for *Seto* were found to use train and the remaining chose car for their homebound trip. Whereas, many passengers bound for *Tajimi* were found to stay at hotel rather than returning back home.

Automobile users bound for *Ichinomia* and *Gifu* required slightly longer travel time than usual. However, required travel time and travel distance became extremely longer for the passengers bound for *Kasugai*, *Moriyama* and *Tajimi*, as many roads and bridges were closed to traffic. Particularly, passengers heading for *Tajimi* from Aichi prefecture found only National Road No. 248 opened to use. Consequently, the road was jam-packed as it was used for detour for the trips from Nagoya to *Tajimi* too. In general, many respondents experienced slightly longer travel time than usual. The required travel time and travel distance became longer for the commuters' had to cross Shonai River.

3. PROBE DATA AND GIS ANALYSIS

3.1 Probe Data

Probe data is a method to determine the traffic features on the road network. It is based on the collection of localization data, speed, and direction of travel and time information from an integrated device consists of GPS device and navigator in vehicles that are being driven.

These data are essential source for traffic information, conducting simulation and for most intelligent transportation system. This means that every GPS facilitated car acts as a sensor for the road network. Based on these data, traffic congestion can be identified, travel times can be calculated, and traffic reports can be rapidly generated. In distinction to traffic cameras, number plate recognition systems and sensor loops embedded in the roadway, no additional hardware on the road network will be necessary.

In Japan, most of the Taxis are generally equipped with GPS system, in order to improve service and efficiency. The GPS information from Taxis is found very useful as a source to assess to the real situation of the congestion due to the typhoon. Thus, this study uses the Taxi probe data for analysis. The data was received from Taxi probe Research Center. The information includes positioning with time with a fraction of milliseconds, Speed, Angle, Vehicle status and so on.

We use the data of 20th September for Taxi in Aichi prefecture. The data was recorded in an interval of an average of 200m or 20s while in some cases it varied due to changes in vehicle status or other parameters. In the data, every single vehicle has a unique identification number, speed (which is point speed and classified in a range), angle (which is one of the Euler angles called heading determined the yaw from North (heading) the incline of the front of the vehicle). A detailed vehicle status for example, with passenger, without passenger, out of service, reserve etc. was also available. In our study, probe vehicle is taxi, and therefore vehicle status data plays key significance to recognize the trip origins and destinations.

3.1 GIS Analysis

For any transport study, GIS is well known and the most frequently used application. It can embrace a set of individual database for the study area, which consists of a mixture of spatial, numerical, and perhaps textual data and could be represented by superposition of a separate map layer for each database. Similarly, in this case the database layers plotted concurrently were topographical data, traffic network data, probe vehicle data etc. GIS 'info tool', is one of the most useful feature. It displays a window on the map showing the detail information for the specific point selected by cursor. It is capable of displaying all of the recorded variables for the probe vehicle. By this way, it allows the learning of the entire history at any time. Recently, GIS consist of another promising feature named 'Tracking Analyst', which can track temporal data from disk in real time. It also supports network connections to GPS units and other tracking and monitoring devices, so anybody can map the data in real time. Symbolizing of temporal data and changing in appearance could be done based on temporal attributes. Tracking Analyst Playback Manager could be used to display in site or fixed time data from disk. Chart of temporal data is using Tracking Analyst functionality to build and display a data clock. Tracking tools help to copy attributes for further analysis and to create animation files and the step tool provides a powerful method of querying point features in a tracking layer according to own personalized settings. In some cases, it was used to create and apply actions to alter the data, filter it, or perform operations based on its attributes and/or location, either in real-time data or in fixed-time datasets. Besides, if the time function of a layer is activated it can be operated or managed in a better and advanced way by the controller named 'Time Slider'. This section follows with the data processing procedure and way of merging it with GIS application to serve our purpose.

3.1.1 Data Processing

The data recorded were simply comprised of different location with time tagged information along with point speed records. As in our case, we intend to study the required travel time for the overall trips. Therefore, we calculate the speed from distance and travel time. The data we received were consisting of positioning data with time with a fraction of milliseconds, speed, angle, vehicle status and so on. For a better processing it is essential to transform the raw data into desired indicators. GPS data is the continuous trajectory for any vehicle for the specific duration of recording. Therefore, data reduction process is a necessity to recognise and identify OD trips and required travel indicators thereby. We propose a procedure to cut short the continuous trajectory into trip ends as the followings. In this study, the data processing is program in Java language. The processing procedure includes 3 steps which are adapted from Nobuhiro *et al.* (2009) to suit with our probe data. The procedure is as follows:

- **Identify the Trips by Vehicle Status**

In order to identify the commuter trips, the preliminary step started by utilizing the information on vehicle status. We define the origin of the trip by the change of other vehicle status to having on board passenger and conversely to identify the destination of the trip. The taxi trip without passengers is excluded here, as it is well understood that, the driver will be roaming freely without following any standard or usual way of movement, hence will not serve our pupose. As for defining OD trip, picking up and dropping off passengers were indicative for defining as the beginning and end of a trip according to Edward (2003). Therefore, in this research, the criterion of vehicle status was proposed for defining trip starts and ends.

- **Managing Long stops**

The chances of stopping for the vehicle could be while dropping off or picking up passenger, stopping at an intersection or taxi rank (Edward, 2003). As for first instances, it needs more than 20 seconds (Edward, 2003) and sometime as long as 2 minutes for paying taxi fare and preparation for getting out of the taxi. Besides while the taxi is waiting at a signalized intersection for the duration as long as 2 minutes or more it became difficult to distinguish between a genuine trip end and just stopping there. This research is concentrated on the congestion situation, so these data are more crucial to consider. As a result, these cases were judged either the vehicle is occupied or not. Our concern is very specific on the situation that it was on the eve of a typhoon and it was observed in several instances that the traffic congestions were severe therefore it was expected for the taxis waiting long time at the signalized intersection even with the passenger. Therefore, long stops at the intersection or on the road, carrying passenger play significant role for the determination of travel time for any trip. However, if the stop is too long we also consider it as a destination and as start a new trip when taxi start to move again.

- **Determining outbound trips**

In this research, we consider homebound commuters' only. Therefore, it is necessary to filter the outbound trips only. We select only the trip originated from Nagoya to other adjacent cities, as the severe traffic congestion occurred in the outbound direction.

GIS application serves the most for this section. In the data processing all the filtered positioning data were plotted on the GIS map environment. For considering any parameters or characteristics as described above, the data were plotted several times for any final decision or to confirm the way of modification.

3.1.2 GIS Output and Analysis of Travel time:

The total data of more than 720,000 records were processed and plotted on the GIS map environment for a better understanding of the congestion situation on the day of typhoon. The GIS simulation was performed for the day of 20th September, 2011 as in Nagoya the downpour situation persists on that day. In continuation, several captures will be displayed and a brief description of the overall situation will also be provided along with for a better and expressive understanding.

Figure 2 is displaying the traffic situation from 13:00 for the day of typhoon. Here, the circles are the indicators of taxi probe vehicle positioned at its geographic position at that specific time. As all the data are time oriented, therefore the management of data can be done with the attribute named "Time Slider" as described before. As it is shown in the legend, the slower vehicles are with big sizes and more red in color, while vehicles with decent speed are with different colors as legend information, placed at the bottom right corner of the figure. The usual behavior of traffic flow with some flash congestion can be observed from the figure. From the capture of 13:00, we can perceive the general situation along with usual urban congestion.

The congestion is increased to some degree in the capture of 15:00. As the typhoon forecast and evacuation schedule was announced already. Therefore, the traffic movement may interpret to represent the upsurge in the generation of the trip. Moreover, this capture is representing that, there were some homebound commuters' leave early, according to the previous study, to arrive home safely and to avoid rush. The next capture is exhibiting the congestion status of Nagoya city and around at 17:00. In Nagoya, the downpour starts from around 16:00, which also hinders the regular traffic movement. Besides, the public transport has left stranded the homebound commuters' and left no other choice for their trip return back to home other than automobile such as taxi cars. This overburdens the traffic over capacity and congestion occurred as a consequence. The capture of 20:00 is demonstrating the continuity of traffic congestion. It can be comprehended from the figures that, the congestion or the density of red circles are shifting from the central part of Nagoya city to the surrounding area. It is because; the generation of trip is lessening with time in the central part. And, with time the traffic condition improves in the capture of 22:00 though the National roads for example, No. 19, 155, 248 were still congested to some extent. There was still some congestion visible on National Road No. 19 just before *Tajimi* even until midnight.

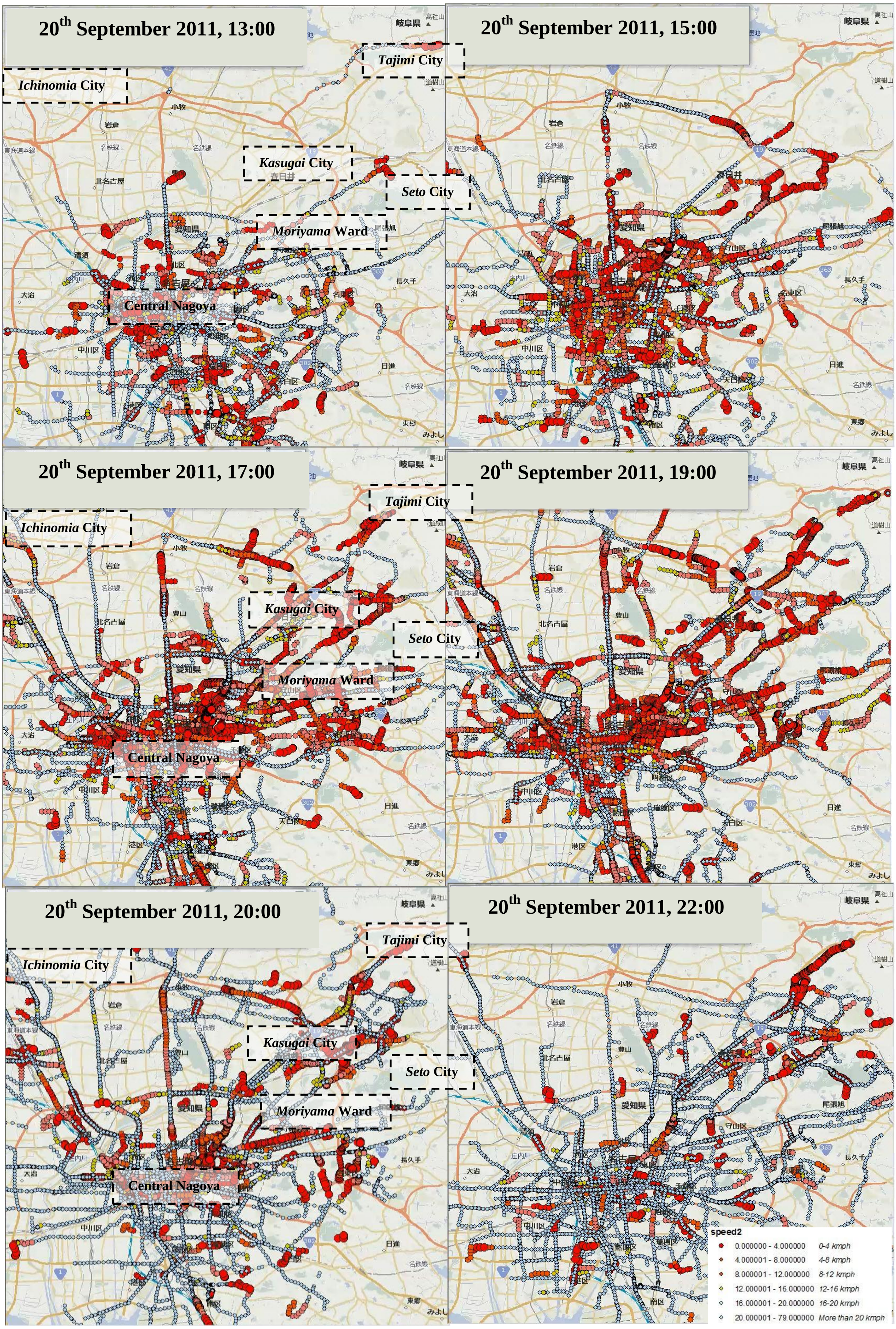
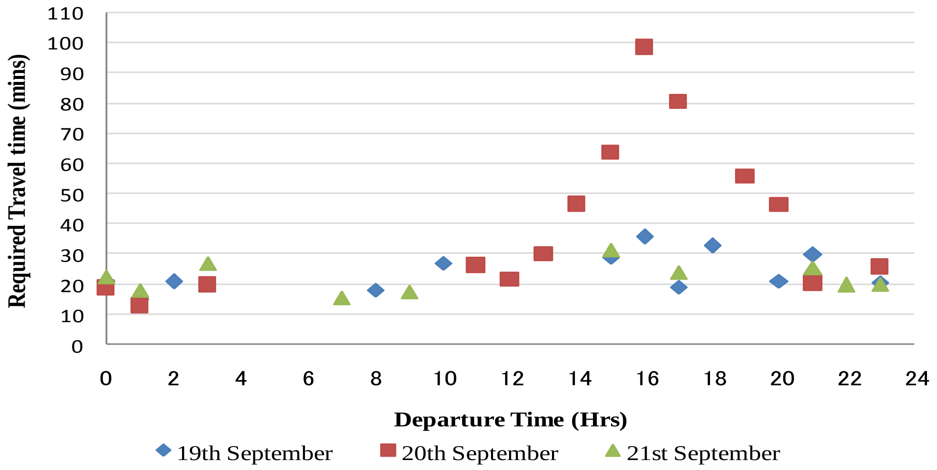


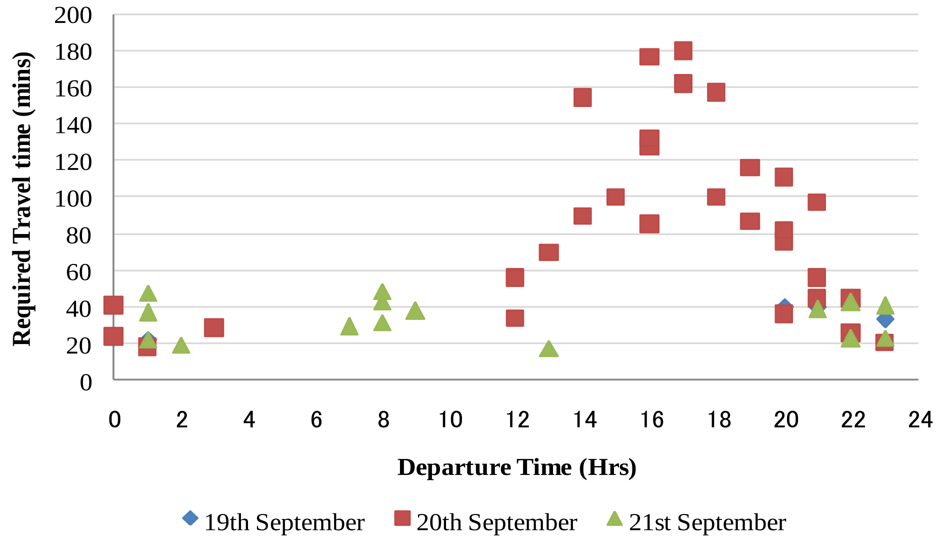
Figure 2: GIS output (Captures of 13:00, 15:00, 17:00, 19:00, 20:00 and 22:00).

Particular attention will be paid to trips originated from the central Nagoya to adjacent cities. In this study, we calculate the travel time for trips originated from *Naka* ward of Nagoya City and destinations were *Moriyama* ward, *Kasugai* City, *Tajimi* City, *Seto* City and *Ichinomia* City. An attempt was made to find the percentage of increment in travel time, as a congestion index comparing with the usual travel time for the day before and after the typhoon. For this purpose, a similar simulation was also performed for 19th and 21st of September.

Travel time was plotted in this graph (Figure 3) at different time of Departure for the trips destined for *Moriyama* ward, which was originated from *Naka* ward. From the graph, travel time has increased to the extent of more than double for trips departed between 15:00 and 19:00. Meanwhile, the usual travel time for 19th and 21st of September are similar.



(i) Required Travel time (mins) for Moriyama Ward



(ii) Required Travel time (mins) for Kasugai City

Figure 3: Graph showing the difference in travel time at different time of Departure.

Similarly, the travel time was also increased for trips bound for *Kasugai*. We also noticed a sudden increment in Taxi trips for the disaster situation. It is generally very rare to find taxi probe data for some duration of time in normal days, because the distance is too far for a taxi trip.

We can observe the similar characteristics for the entire destination. Hence, let us find the percentage of increment of travel time for different destinations.

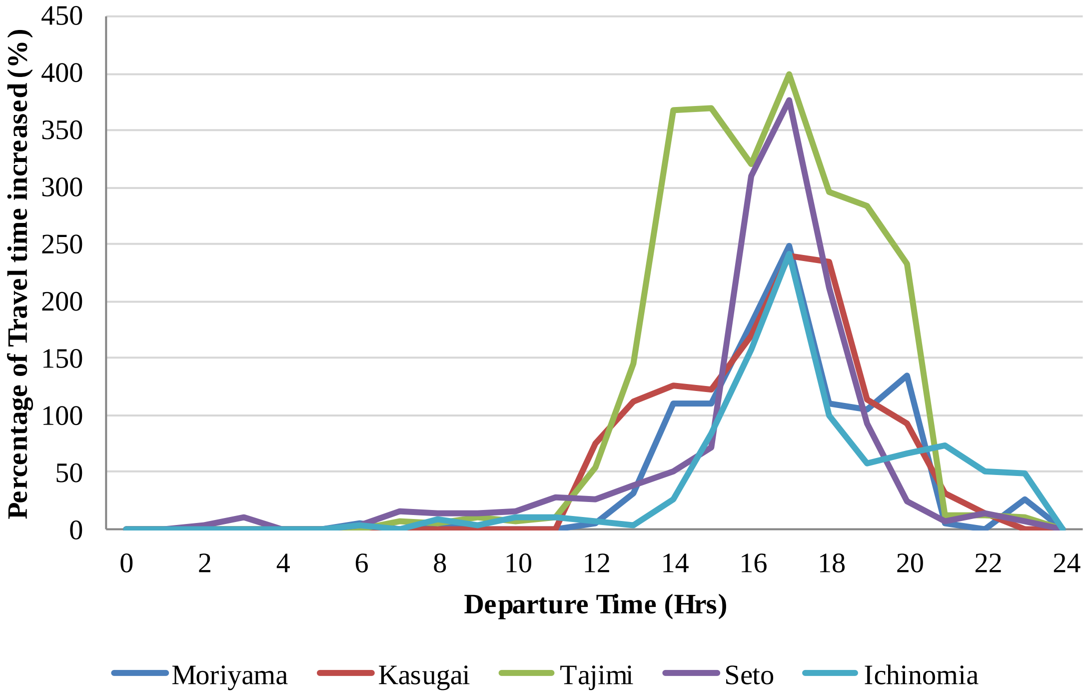


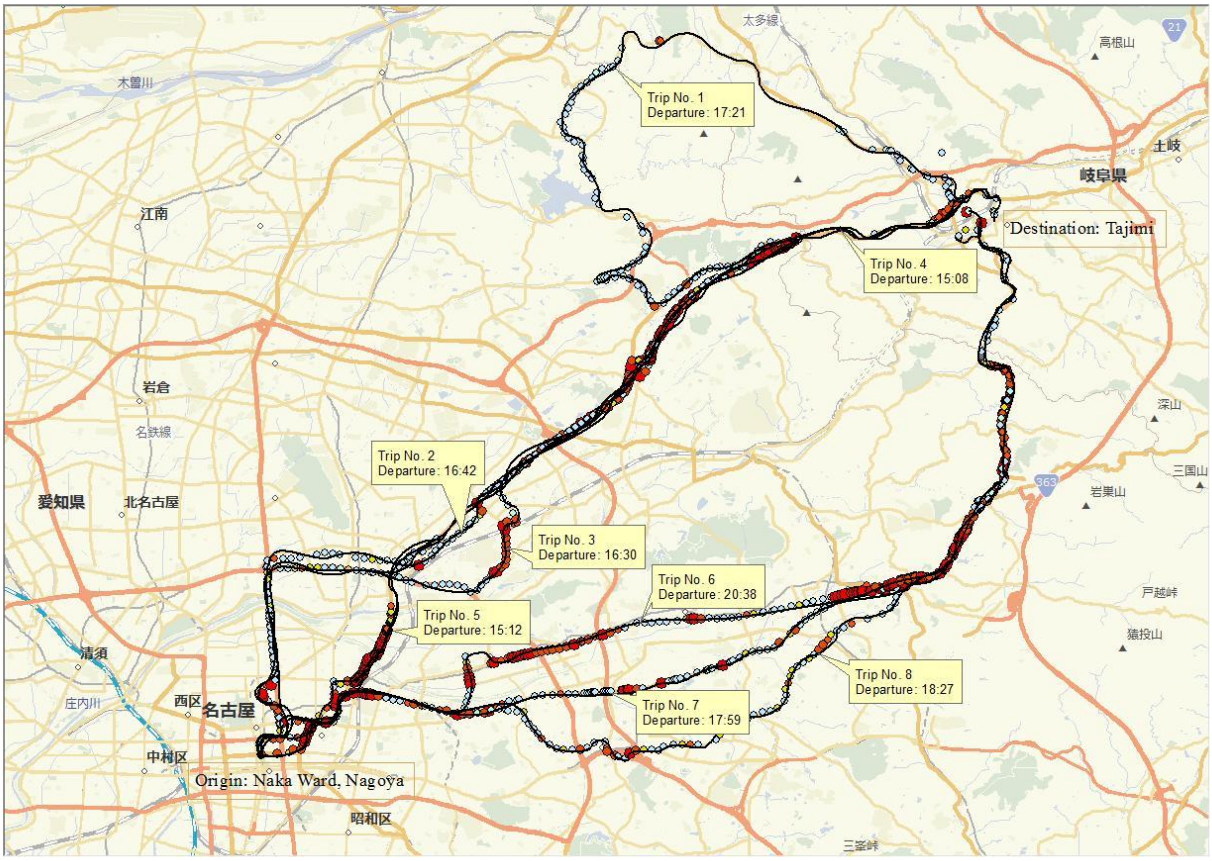
Figure 4: The percentage of travel time increased for trips originated from central Nagoya to different destination at different departure time.

From Figure 4 we perceive that, the maximum augmentation in travel time occurred for the passenger originated from center of Nagoya destined for *Tajimi* City which was about 4 times more than the regular travel time; whereas, the travel time become about 3.75 times for *Seto* City, 2.5 times for *Moriyama* ward, *Kasugai* and *Ichinomia* City. Besides, trips to Tajiimi City have faced very longer travel time if departed during 13:00 to 19:00. The widest band was found for trips to *Moriyama* ward *Kasugai* city, which means that the congestion took the longest duration on departure time of 12:00 to 21:00 comparing the other destinations.

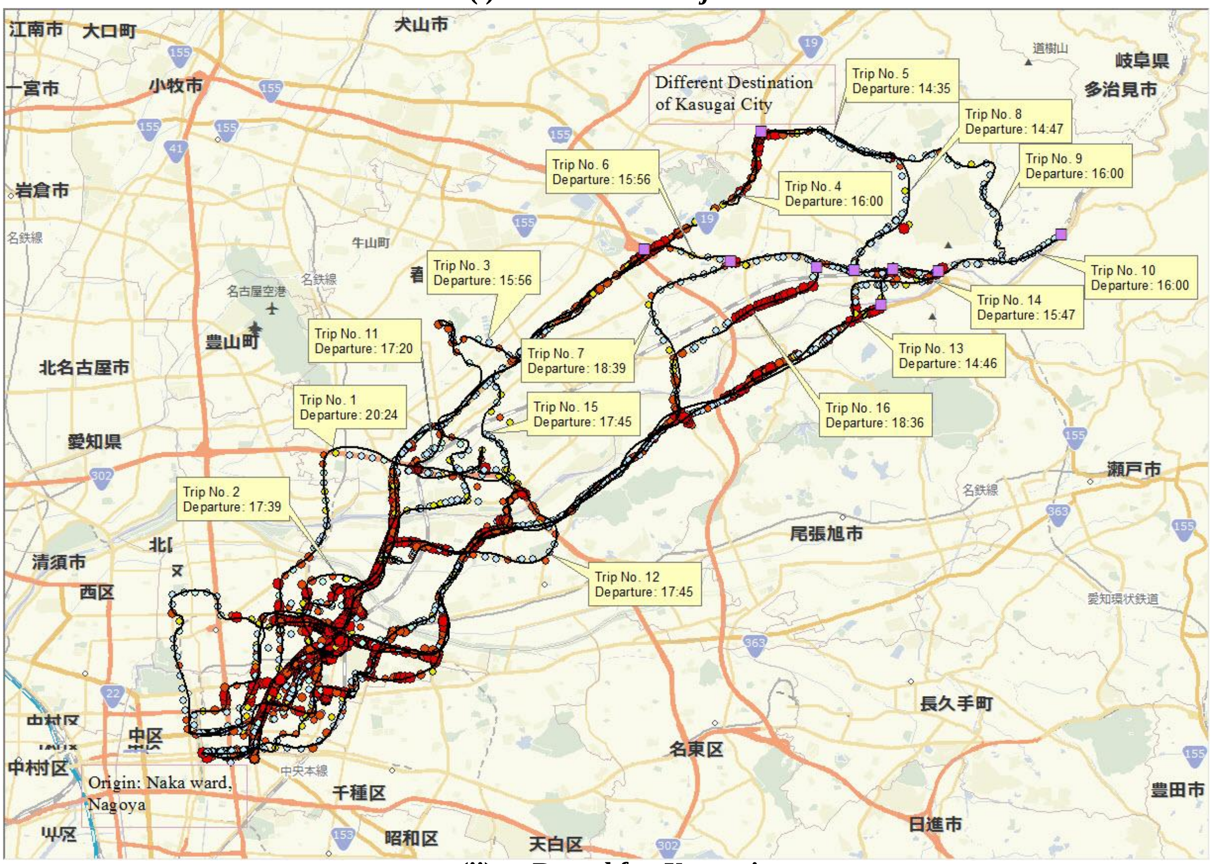
4. COMPARING RESULTS BETWEEN THE QUESTIONNAIRE SURVEY AND PROBE DATA ANALYSIS

In this section a comparison study between the findings from one questionnaire survey and from probe data will be presented. For better comparison, only the trips with the same origins and destinations as one in questionnaire survey were selected.

Firstly, in this section we will explore the route followed for the trips. The probe data provides more precise traveled route comparing with questionnaire survey. It was very difficult to en-route the trips for questionnaire survey, because of lack in detail information.



(i) Bound for *Tajimi*



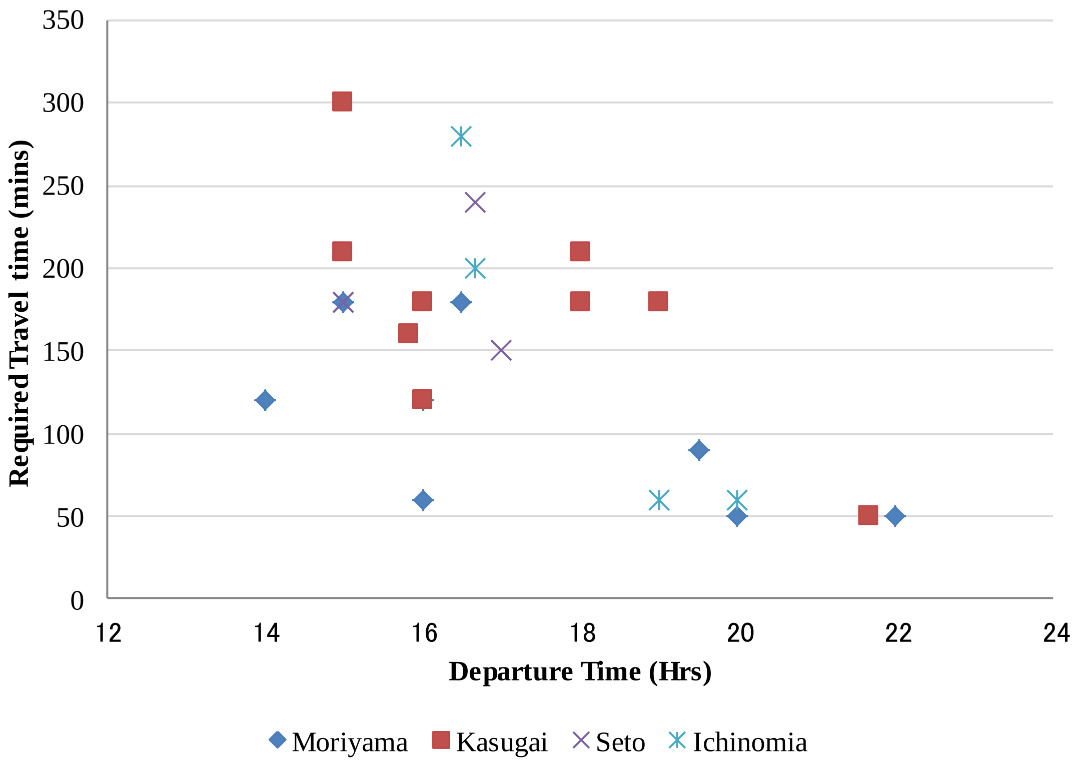
(ii) Bound for *Kasugai*

Figure 5: Different routes occupied by Taxi for two different destinations.

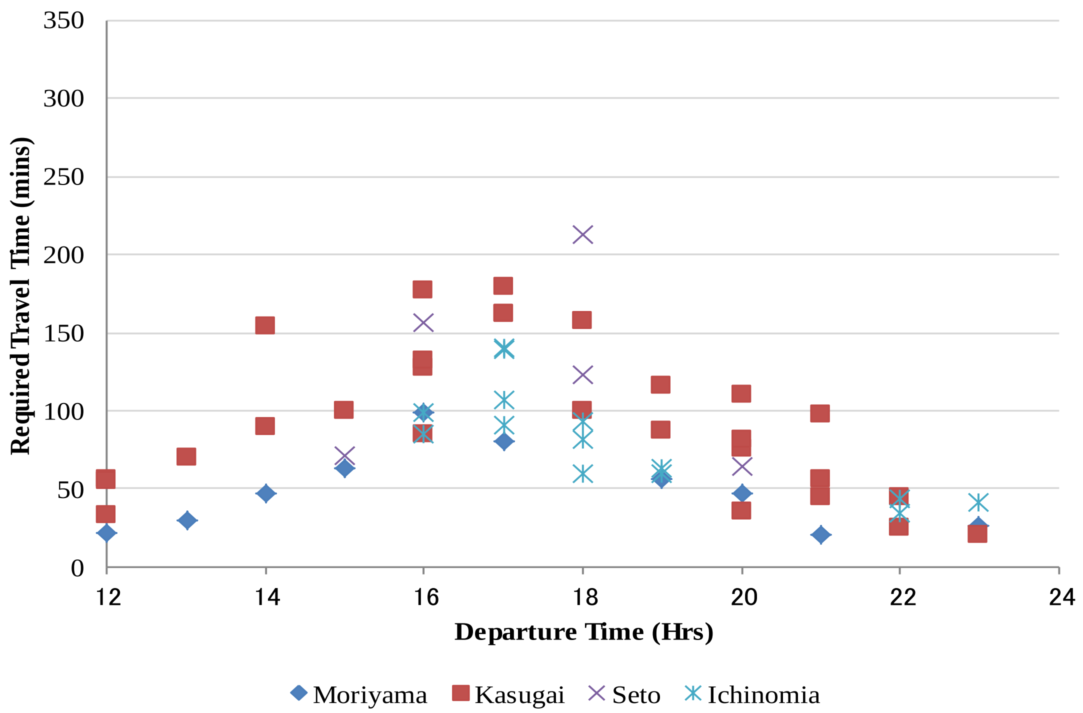
Figure 5 demonstrates different trips drawn by dark lines along with the information on departure time for different respective trips. The legend shows the sizes and colors of different points indicating their speed value respectively. We noticed huge varieties of movements, though the Origin and Destination points were just few meters apart. Though the most detail information was not provided for questionnaire survey but we tried to route them and we find some trips matching with the trips drawn in the figure.

In Figure 5(ii) the destination is *Kasugai* City and hence the trip is more in number than *Tajimi* (Figure 5(i)). Both of the captures were prepared under the circumstance of heavy congestion as described earlier in GIS output.

Now, if we look for the comparison in travel time, we find the similarity in behavior for both of the cases. Figure 6 (i) shows the distribution of travel time variation for commuters' from center of Nagoya to other cities from Questionnaire Survey. As the survey was conducted on the victims of the typhoon and the downpour has started from 16:00; thus, we cannot find data of departure before 15:00. We can observe from the graph that, a huge upsurge occurs in travel time for the trips from Nagoya to *Kasugai*. As Road no. 19, which is the main road to *Kasugai*, was shut down at that time, resulting in severe traffic congestion on roads around there. Besides, there are no specific patterns or trend can be understood from the graph. We can see that some travel time values are quite strange because, there were wide variation of travel time with the same departure time. We suppose this can be one of the shortcomings of questionnaire survey as the responders sometimes answer from the feeling, not from the exact that they actually spent. Besides, the responders used private vehicles other than taxi were also included as the subject of questionnaire survey. But it can be remarked easily that, the travel time has an increasing attitude for entire destinations from 15:00 to 20:00. Figure 6 (ii) shows the distribution of travel time for the same OD trips from the analysis of Probe data. We can easily understand a trend of travel time at different time of departure. However, it was very difficult to find the similar trip as in the questionnaire survey for the destination of *Tajimi* in the probe data, because the distance is too long and too expensive for a taxi trip. Therefore, the trips for *Tajimi* are excluded from this comparison. Both the results from the questionnaire and probe data show an increment in travel time for departure time during 15:00 to 20:00. From both of the graphs, we can conclude that probe data and questionnaire survey interpret similar understanding, but probe data is relatively more reliable. Probe data provides better information as it covers broader range of trips departure time, origins and destinations. In addition, the increasing and decreasing trend of congestion by duration can be observed easily by the probe data. Whereas, the questionnaire survey cannot give continuous information as it is very difficult to find enough samples from the survey. However, for long distance trip (such as, from Nagoya to *Tajimi* is more than 42 km), the questionnaire survey can be used as a supplement information to cover these missing trips from probe data.



(i) Travel time for trips from Nagoya at different Departure time for questionnaire survey



(ii) Travel time for trips from Nagoya at different Departure time from probe data

Figure 6: Graph showing the variation in travel time from Questionnaire Survey and Probe data

5. CONCLUSION

This paper has presented a method to utilize GPS data with GIS technique to assess to traffic impacts from typhoon, in which the data on taxi probe car facilitated with GPS system was used for analysis of the effects of typhoon Roke focusing especially for the commuters' homebound trips. And this paper has analyzed and compared the results from probe data and one's questionnaire survey, explored the advantages and disadvantages of both methods,the most congested sections and their severity are presented accordingly. Among the various sensing technologies developed in the area of ITS, the probe vehicle survey using GPS is regarded one the most practical and effective methodologies to obtain the information on the spatial changes in traffic condition on road network. We find similar analytic reports from our study too. We can observe from the output that, the pattern of travel time is well organized and more practical. As enormous unbalanced condition is more obvious and expected for the case of questionnaire as we also see from the graph, because of mixing of the feeling along with while responding. From probe data the increment of travel time for trips to *Tajimi* was 400% more than usual, 375% for *Seto*, and about 250% for *Kasugai* and *Moriyama*. Similarly from the finding of questionnaire suvey, we observed 330% more than usual for *Tajimi*, 370% or more for *Kasugai* and *Moriyama* and around 170% for others. According to the comments in questionnaire, National Road no. 19 was closed to traffic; therefore, National Road No. 248 was very crowded. This information was perceived in the simulation too.

As the study was operated for Taxi probe data, therefore the trip selection and picking up data was the major concern. While GPS technology alone is not perfect, is a good trade-off for missing numerous data. The information may be missed due to satellite loss, urban canyons, dense tree cover, or short trips that do not allow time for GPS receiver to establish correct position. Besides, as programming software was used to filter out data therefore, cases may also happen like misjudgement of data, missing short links and technical inappropriateness etc. We can not get the information of the long distance trip, while it can be captured by questionnaire survey. Besides, for questionnaire survey the exact situation may not be interpreted. Concerning all these fact we can not boldly state that, this is the best way for traffic analysis. But we can emphasize this methodology as a better, more reliable, advanced and user friendly mode of investigation.

Data reporting is the most useful aspect of GPS, as it displays the output of any analysis or estimation and consequently plays an important role in decision making. The main objective of using probe data is to have a better representation of the results achieved from the analysis made. GIS have a significant role in not only storage and analysis but also reporting of different data sources with details. As Taylor *et al.* (2000) also mentioned, GIS could identify the zones of traffic congestion through the integration of probe data with other set of individual databases for the study area. Therefore, we are looking forward to utilizing and implementing data reporting in further research to enhance the efficiency of traffic management. For example, to identify the bottlenecks and suggest countermeasures to alleviate traffic congestion in the future typhoon.

REFERENCES

Edward, C., Majid, S., Yasunori, M., Ryota, H., Masao, K. "Cleansing of Probe car data to determine Trip OD." *21st Australian Road Research Board Conference.* Cairns, Australia: ARRB Group Limited, 2003. 12.

Liang, Z., Jian-Min, X., Ling-Xian, Z. "Arterial Speed Studies with Taxi Equipped with Global Positioning Receivers As Probe Vehicle." *International Conference of IEEE, Vol. 2,* 2005: 1343-1347.

Fujita, M., Jun, M., Koji, S. "Behavioral Analysis of Homebound Public Transport Users During Downpour Conditions." *Journal of the Asian Transport Studies, Volume 1, Issue 3*, 2011: 318-333.

Murakami, E., Wagner, D., P. "Can using global possitioning system (GPS) improve trip reporting?" *Transportation Research Part C 7*, 1999: 149-165.

Nobuhiro, U., Fumitaka, K., Hiroshi, T., Yasunori, I. "Using Bus Probe Data for Analysis of Travel Time Variablity." *Journal of Intelligent Transportation System, 13(1)*, 2009: 2-15.

Oohashi, M., Fujita, M.,. “Analysis on the context of commuting victims and emergency evacuation in Tokai area during Typhoon Roke on 2011.” JSCE Conference. 2012. 1-6. (in Japanese)

Quiroga, C.A., Bullock, D.,. "Travel time studies with global positioning and geographic information systems: an integrated methodology." *Transportation Research C 6C (1),* 1998a: 101-127.

Taylor, M., A., P., Woolley, J., E., Zito, R. "Integration of the global positioning system and geographical information systems for traffic congestion studies." *Transportation Research Part C 8*, 2000: 257-285.

Tomio, M., Takaaki, S., Taka, M. "Route Identification and Travel Time Prediction Using Pobe-car Data." *International Journal of ITS Research, Vol. 2, No. 1*, October 2004.

Zito, R., D'este, G., Taylor, M. A. P. "Global Positioning Systems In The Time Domain: How Useful A Tool For Intelligent Vehicle-Highway Systems?" *Transportation Research Part C, Vol. 3, No. 4*, 1995: 193-209.

Zito, R., D'este, G., Taylor, M., A., P. "Global positioning systems in the time domain: How useful a tool for Intelligent Vehicle-Highway Systems?" *An International Journal of Transportation Research Part C, Vol. 3, No. 4*, 1995: 193-209.