Analysis of traffic congestion due to Typhoon using taxi probe data

Mohammad Hannan Mahmud KHAN[1], Wisinee WISETJINDAWAT[2] and Motohiro FUJITA[3]

[1]Graduate Student, Graduate School of Engineering, Dept. of Civil Eng., Nagoya Institute of Technology
(Gokiso, Showa, Nagoya 466-8555, Japan)
E-mail: cjk13589@stn.nitech.ac.jp
[2]Member of JSCE, Assistant Prof., Dept. of Civil Eng., Nagoya Institute of Technology
(Gokiso, Showa, Nagoya 466-8555, Japan)
E-mail: wisinee@nitech.ac.jp
[3]Member of JSCE, Professor, Dept. of Civil Eng., Nagoya Institute of Technology
(Gokiso, Showa, Nagoya 466-8555, Japan)
E-mail: fujita.motohiro@nitech.ac.jp

Severe traffic congestion often occurred due to typhoon. It is important for planners to understand the level of congestion as well as the bottlenecks due to the disaster. However, it is very difficult to gain assess to the real situation of the congestion under thus event. In previous researches, many analyzed the information from questionnaire survey. As the questionnaire survey can sometimes result in many mistakes or biases from responders; in this research, we therefore, utilize the data of taxi probe cars for analysis of the effects of typhoon focusing on the commuters' homebound trips.

Key Words : *probe data, typhoon, traffic congestion, homebound commuters'*

1. INTRODUCTION

On 20th September, 2011, Japan has experienced one of the most severe typhoon named Typhoon Roke. Over a million people in Nagoya, which was more than double the numbers victims forced to evacuate[1)]. Comparing to the previous disaster, Nagoya faced huge traffic congestion on the day of typhoon.

Some bridges and roads were also shut down, as there were high wave introducing overflowing of local rivers, flash flood and land slide due to excessive rainfall on the day of typhoon. Besides, public transport were stopped early to avoid possible massive damages. Therefore, the traffic load was increased on roadways. At the same time only a few roads was opened in public, which added new dimension to the severity.

As it is well understood that, we can not alleviate traffic congestion completely. Although it is not expected especially in the emergency situation, when each and every second counts. At the time of disaster, it is the task to equipoise the increased traffic volume with available capacity. In spite of that, constraints of emergency situation are not the solely matter to consider for any roadway design. Hence, achieving a better understanding about the congestion intensity is much necessary for the planners to assess the bottleneck and to handle excess traffic on emergency situation.

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 probe car facilitated with the Global Positioning System (GPS), which collects information on position, speed, vehicle status and direction of travel on the day of typhoon. At this modern age, conventional database systems are replaced by GPS based data recording tool for its spatial integration such as latitude and longitude with other relevant databases. The use of 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 developing moving car or moving observer method of traffic stream measurement to provide simultaneous measurement of traffic stream variables[2]. Recently, there are only a few studies focused on the situation during disaster, which is more crucial in the case of typhoon. Fujita et al.[3] analyzed individual behavior and awareness of disaster prevention among public transport users for the future downpour through a questionnaire survey. Despite of having some drawbacks, Murakami and Wagner[4] 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 tried to visualize and interpret the intensification of travel time for specific OD trips on the day of typhoon, which was facilitated by the application of GIS.

2. PROBE DATA

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 on the road network.

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.

We use the data of 20th September for Taxi in Aichi prefecture. 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 recorded. In our study, probe vehicle is taxi, and therefore vehicle status had key significance to identify the trip origins and destinations.

3. 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. This section follows with the data processing procedure and way of merging it with GIS application to serve our purpose.

(1) Data processing

The data recorded are simply comprised of different location with time tagged information along with point speed records. As in our case, we intend to find 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, 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.[5] to suit with the probe data we received.

a) Identifying OD trips

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 and will not follow any standard or usual way of movement, hence will not serve our pupose. As for defining OD trip, picking up and dropping off passengers was indicative for defining as the beginning and end of a trip. Therefore, in this research, the criterion of vehicle status was proposed for defining trip start and end.

b) Handling long stops

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. As for this research these data are more essential to consider as we were concentrating on the congestion situation. As a result, these cases were judged either the vehicle is occupied or not. According to our concern, it is very specific on the situation that it was on the event of typhoon. And it was observed in several instances that the traffic congestion were severe. Therefore, it was expected for the taxis waiting long time at the signalized intersection even with the passenger. For that reason, long stops at the intersection or on the road, carrying passenger plays significant role for the determination of travel time for any trip. However, if the stop is too long we also considered it as a destination and as start a new trip when taxi starts to move again.

c) Defining outbound trips

Only homebound commuters' were considered in this research. Therefore, it is necessary to filter the outbound trips only. We selected only the trip originated from central part of Nagoya to other adjacent cities, as severe traffic congestion occurred in the outbound direction.

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

(2) GIS output

More than 720,000 records were processed and plotted on the GIS map environment for a better understanding of the congestion situation. 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 understanding.

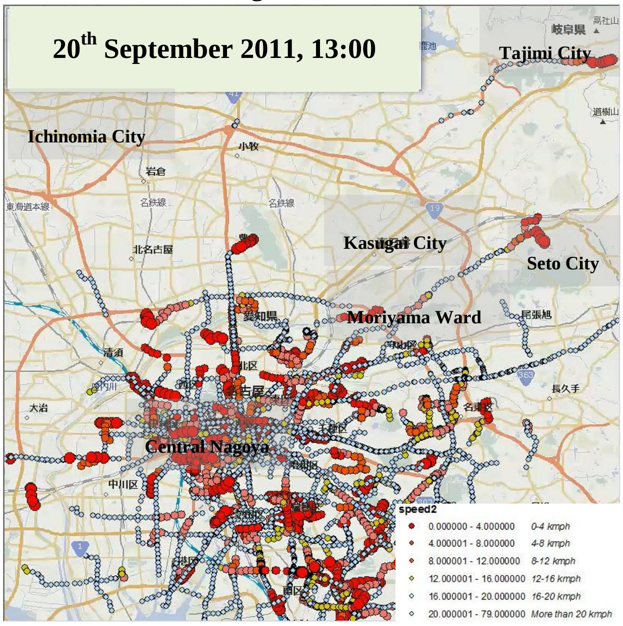

Fig.1 Capture of 13:00 as GIS output.

Fig.1 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 location 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 it is shown in the legend, the slower vehicles are with larger sizes and deep 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.

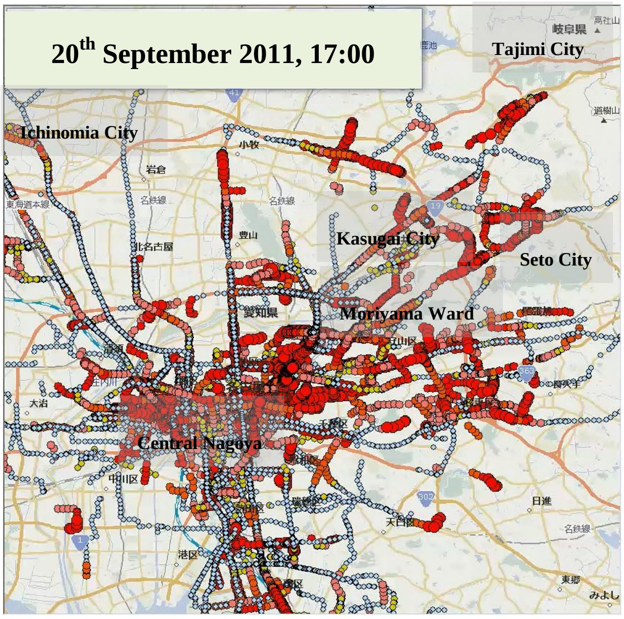

Fig.2 Capture of 17:00 as GIS output.

In **Fig.2**, we can observe the congestion status of Nagoya city and around at 17:00. As the typhoon forecast and evacuation notice was announced already, therefore, a huge upsurge in the generation of the trip was noticed at the central part. Besides, the downpour starts from 16:00 in Nagoya, which also hinders the usual traffic flow. As a consequence of downpour, the public transport has left stranded the homebound commuters and left no other choice for their return trip other than automobile. Consequently the severity of congestion was increased.

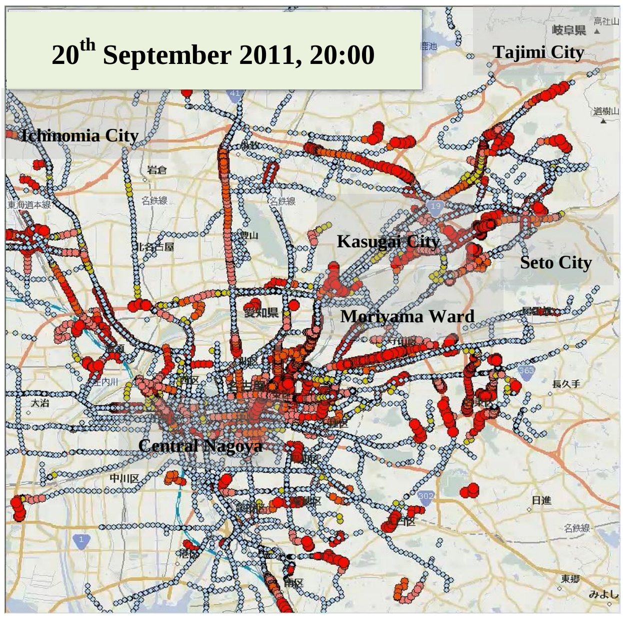

Fig.3 Capture of 20:00 as GIS output.

Comparing **Fig.3** with the others, it can be comprehended 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. In addition, we found National roads No. 19, 155, 248 are still congested to some extent even at late hours of night.

4. ANALYSIS OF TRAVEL TIME

The analysis of travel time was run from the data that represents the actual situation by GIS application. The data were exported from GIS environment and explored quantitatively for a representable understanding of the severity on the day of typhoon.

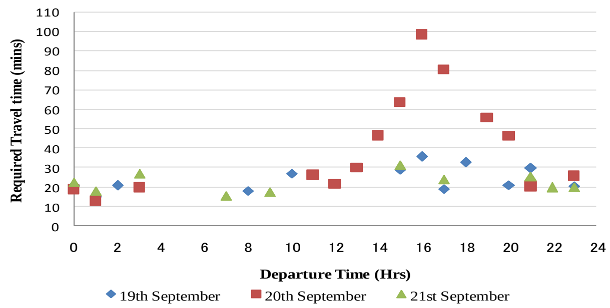

Fig.4 Travel time required for Moriyama ward.

Travel time was plotted in **Fig.4** 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.

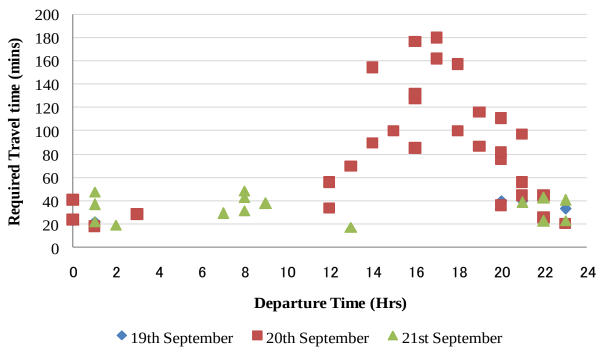

Fig.5 Travel time required for Kasugai City.

Similarly, the travel time was also increased for trips bound for Kasugai. We also noticed in **Fig.5** 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 observed the similar characteristics for the entire destination. Hence, let us find the percentage of increment in travel time for different destinations.

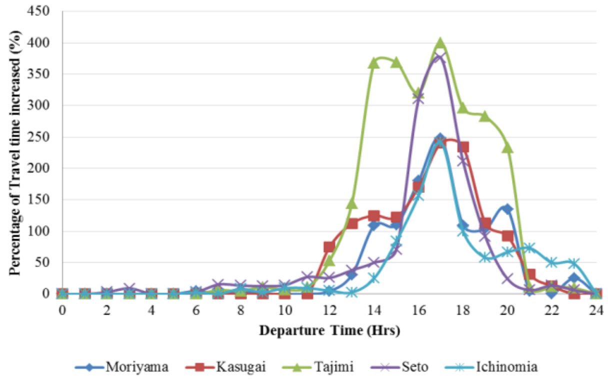

Fig.6 Percentage of travel time increased for different trips from central Nagoya to different destinations.

From **Fig.6** we perceive that, the maximum intensification 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 longer travel time if departure is during 13:00 to 19:00. The widest band was found for trips to Moriyama ward and Kasugai city, which means that the congestion took the longest duration for the departure time of 12:00 to 21:00 comparing other destinations.

5. CONCLUSION

In this paper we have presented a method to exploit GPS data with the help of GIS technique to assess the traffic impacts from typhoon. As it is important for planners to understand the level of congestion as well as the bottlenecks due to such disaster. For acquiring the information on the spatial changes in traffic condition on road network the probe vehicle survey using GPS is regarded as one of the most practical and effective methodologies among the various sensing technologies developed in the area of ITS. The analysis result from probe data demonstrate that, the increment of travel time for the commuters' homebound trips was really severe. Besides, travel time and distance became extremely longer for passengars bound for Kasugai, Moriyama and Tajimi, as many roads and bridges were closed to traffic. As, National Road no. 19 was closed to traffic for sometime; therefore, passenger bound for Tajimi found only National Road No. 248 as a detour and make it more crowded.

As the study was operated for Taxi probe data, therefore the trip selection and picking up data was the major concern. While GPS technology can be 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 sort out data therefore, cases may also happen like misjudgement of data, missing short links and technical drawbacks etc. We can not get the information of the long distance trip, while it can be captured by questionnaire survey. Besides, for questionnaire survey can sometimes result in many mistakes or biases from responders. Concerning all these fact we can suggest probe car data analysis as a better, more reliable, advanced and user friendly mode of investigation.

We are looking forward to utilize and implement data reporting in further study to enhance the efficiency of traffic management by identifying the bottlenecks and suggest countermeasures to alleviate traffic congestion in the future typhoon.

REFERENCES

1) Wikipedia website about the typhoon situation (http://en.wikipedia.org/wiki/Typhoon_Roke_(2011))
2) Quiroga, C.A., Bullock, D. : Travel time studies with global positioning and geographic information systems: an integrated methodology., *Transportation Research C 6C (1)*, pp. 101-127, 1998a.
3) Fujita, M., Jun, M., Koji, S. : Behavioral Analysis of Homebound Public Transport Users During Downpour Conditions., *Journal of the Asian Transport Studies*, Vol. 1, Issue 3, pp. 318-333, 2011.
4) Murakami, E., Wagner, D., P. : Can using global possitioning system (GPS) improve trip reporting?, *Transportation Research Part C 7*, pp. 149-165, 1999.
5) 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)*, pp. 2-15, 2009.