(32) Developing of Animated Simulation Using Taxi Probe Data during a Downpour Disaster

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

[1]Student member of JSCE, Graduate Student, Dept. of Civil Eng., Nagoya Institute of Technology
(Gokiso, Showa, Nagoya 466-8555, Japan)
E-mail:cjl13501@stn.nitech.ac.jp
[2] 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
[3] 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

Traffic congestion is unacceptable during an emergency. Congestion does not only cause delay to returning home commuters but also impede emergency vehicles. It is necessary to identify the congestion location in order to find the causes and countermeasures to alleviate its severity. In this study, we prepare an animated simulation of returning home behavior of commuters during a downpour. A taxi probe data was used to prepare the simulation. However, visualizing the raw data directly does not produce an understandable representation of the real traffic situation.

This study aims at reproducing efficiently the real traffic situation under such condition that can be easily recognized by a simple and quick glance. This paper discusses the method to reproduce the data. The proposed method provides a better realization of the traffic condition. The animated simulation can be used to explore the level of congestion in numerous locations and to evaluate the performance of countermeasures to overcome the congestion.

Key Words : *probe, commuter, return home behavior, downpour, congestion, simulation*

1. INTRODUCTION

In recent years, coastal cities including Nagoya, Toyota, and Ise have been facing a series of downpour disaster quite frequently. For example, on 20th September 2011 Nagoya city experienced a devastating downpour caused by Typhoon Roke.

Strong winds and driving rain led to the cancellation of train services in Nagoya. Moreover, several companies were forced to close the facilities as a precaution. This situation increased the number of commuters bounded for home. Consequently, they chose to travel by cars as the only available option for returning home. This produced an additional traffic load. Flash floods and extreme river waves covered roads and bridges. It reduced the road capacity and generated a further dimension of congestion severity.

During emergency, severe congestion is not welcomed since it related to life and death of victims. Therefore, alleviating congestion is one of the greatest challenges in traffic operations. As a result, this study tries to establish a traffic simulation to inspect the performance of countermeasures to alleviate traffic congestion.

Most of the recent studies focus on pre-disaster evacuation and post-disaster network reconstruction[1)]. However, quite a few studies worked on the situation during a disaster, which is further subtle on typhoon as a catastrophe. Hiroi et al. [2)] conducted a questionnaire survey to study and discuss the usage of smart technology while returning home during an earthquake. Kazuyuki et al. [3)] developed models to describe the preference for returning home during an earthquake. Though these works investigate on the returning home passengers, yet lack considering downpour situation.

Study on downpour situations, such as Fujita et al. [4)] focused on individual attitude and awareness of typhoon evacuation among public transport users for any future downpour using a questionnaire survey. However, an analytic approach is absent there even though it is among quite a few studies focusing typhoon.

In addition, Khan et al.[5] investigated the GIS approach using taxi probe data and examined the travel time accuracy. Even it discussed the potential for using probe data over traditional survey data, the development of a validation system was lacking there.

The previous literatures reveal that no existing analysis focused on the commuters returning home through roadway while no other possible travel mode during a heavy torrential rain event. They also lacked the presence of an animated real-time simulation in this context. Our simulation will be helpful in overcoming this lack of a well-developed simulation. It could find applications that include exploration of level of congestion intensities in several locations and also can be used to evaluate the performance of countermeasures.

2. OUTLINE OF TAXI PROBE DATA

We used taxi car as probe vehicle in which the data was received from a Taxi Probe Research Center. The vehicle is capable of sending the data of Positioning with time, Speed, Angle and Vehicle status. A good number of GPS device installed cars (taxis) was left moving in a traffic stream.

We have received the recorded data for three consecutive days, 19th to 21st of September 2011 for 72 hours long. The recording interval of recording the data was an average of 200m traveled path and 20s of travel duration. The location for recording is Aichi prefecture with most of the vehicles moving in and around Nagoya city. As our probe vehicle is a taxi car therefore, vehicle status data such as with/without passenger were important concern in the data preparation and analysis as well.

3. CREATING THE BASIC ANIMATED SIMULATION DURING DOWNPOUR DISASTER

In this section, we construct the basic animated simulation using taxi probe data to represent the congestion severity around Nagoya city during downpour disaster.

The purpose of this simulation is to communicate with drivers for a better recognition of the congestion severity during disaster. In general, the number of

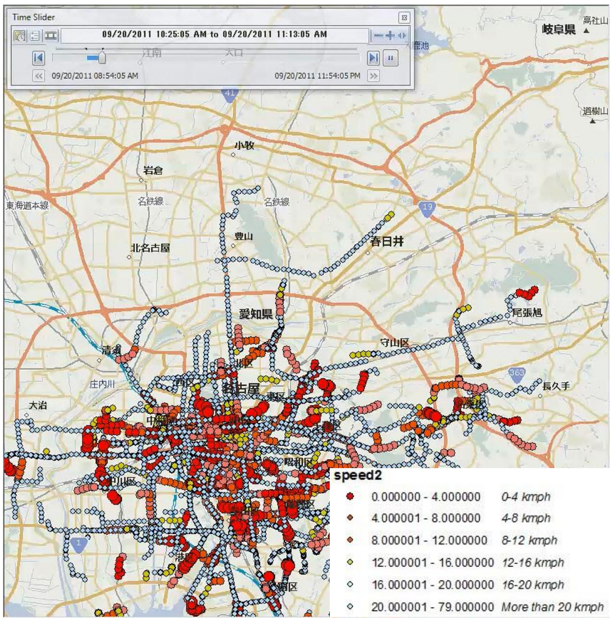

Fig.1 Simulation Output window

Table 1 Factors for different speed classes

Speed Class	Multiplication Factor
0 – 4 km/h	4
4 – 8 km/h	4
8 – 12 km/h	4
12 – 16 km/h	1

probe data during disaster is inadequate to represent to real traffic situation. Especially, when the congestion level is worsening, the probe cars cannot enter to the traffic; hence the number of probe data becomes much smaller. During severe traffic congestion, the probe vehicles are also strictly running along with other vehicles in the traffic stream. It is possible to consider that other vehicles exist in between the probe vehicles. This study prepares a visualization of the probe vehicles with a proper size and color for a better representation of the congestion level. In addition, using the probe vehicles cannot represent other vehicles in between the probe cars. Thus, the probe data are expanded to represent the other following vehicles in the traffic stream.

GIS is used to prepare the simulation. In **Fig.1**, a lot of circles with difference in size and colors are shown. These circles denote probe data for that time window. Time window is the particular period of time, for which length the data are plotted on a single frame. As in the legend, the size and color vary according to the speed classes. The slower vehicles are with larger sizes and the most red in color.

GPS data was recorded as the vehicle changed its position for a particular distance. It resulted in fewer data for the lower speed vehicles. Therefore, representation of unmodified data would obviously underestimate the real situation. For this reason, we require augmenting the lower speed values to the extent of real life data volume.

We proposed the multiplication factors as in **Table 1**, for different speed classes. We achieved this factor after experimenting with a number of patterns. These factors were implied to develop the simulation that demands a validation of the output. We could not validate the output in the previous study. Therefore, in this study we would do the evaluation to propose a well suited pattern of multiplication factor for the better portrayal of the actual situation.

4. METHODOLOGY

(1) Data Transformation

GPS contains huge dataset to track the vehicle down along its route that makes the dataset large in volume. To process the data, we transformed the raw data into desired indicators. We used Java platform to facilitate data transformation.

a) Preparation of Probe data

The origin of any trip is defined by the change of another vehicle status to occupied status contrary to determine the destination of that trip. In this research, we proposed vehicle status as an indicator to define origin and destination of a trip.

We used the probe data as a benchmark dataset to perform the experiment. Probe data consisted of travel information for a number of taxis' wherein every Taxi runs multiple trips. We stored travel time and distance traveled for every change in position for each trip by the difference in the time stamp and by determining linear distance respectively.

b) Preparation of Simulation data

To mimic the actual situation, we proposed several patterns of data expansion. We factored the number data regarding their speed classes to prepare the simulation environment, including the pattern we chose so far, as in **Table 2**.

We proposed to set the time window for 48 minutes therein. We further augment the dataset in order to make the dataset similar in volume to the simulation dataset.

Table 2 Pattern distribution for Simulation data

Speed Class	Pattern 1	Pattern 2	Pattern 3	Pattern 4	Pattern 5
0 – 4 km/h	2	3	4	6	12
4 – 8 km/h	2	3	4	5	12
8 – 12 km/h	2	2	4	4	8
12 – 16 km/h	1	1	1	1	1

(2) Data Analysis

We have analyzed the data for the day of 20th September 2011 as the downpour was the most severe on the same day in Nagoya city. Simulation output showed a continuous trajectory of multiple frames for a particular time window. Therefore, firstly, we need to begin the analysis by filtering out the data of a given time window. We considered each test probe data as a square object with a particular area. The initial area of that object was set as the size of the largest circle in the simulation, as the largest one would draw the attention while displaying the simulation output. In this study, we examined three different sizes to determine the most suitable one for the development of the new animated simulation. In **Table 3**, we can observe the pattern development. Firstly, the variation in multiplication factor, from **Table 2**. Secondly, the variations in setting the initial area of the test probe object.

The object traveled through its path and explore for any simulation speed data inside the boundary based on positioning data. The observer would store the top most data in case of multiple data. Concurrently, the observer varies its area while the speed data is not from the lowest speed class. It modified its area for three instances up until to achieve the lowest speed data. On the contrary, it stored a value of 20 km/h as a speed data. This approach is unique, as the probe observer itself was picking up the speed data that is supposed to be displayed.

The concept of changing area of the square object was very essential. It helped to facilitate lower speed classes by varying the area of the squares.

Table 3 Detail distribution of various Patterns

Speed Class	Size of the Observer (m)	Patterns														
		1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C
		52	78	104	52	78	104	52	78	104	52	78	104	52	78	104
0 – 4 km/h		2			3			4			6			12		
4 – 8 km/h		2			3			4			5			12		
8 – 12 km/h		2			2			4			4			8		
12 – 16 km/h		1			1			1			1			1		

So, the observer recorded the speed value which would be displayed in the simulation. Then, we used the distance data of the test probe object to determine the travel time by the speed distance relationship. Next, the data were grouped by vehicle and particular trips to achieve the overall travel time for any given trip. Finally, both of the travel time, traveled in actual by probe data and data recorded by the Object probe were compared to visualize the difference.

The whole process was repeated several times for patterns from 1A through 5C (**Table 3**). Then, the performance indices are determined for all of the patterns to propose the most effective pattern for the development of the animated simulation.

4. RESULTS AND DISCUSSIONS

The dataset were analyzed according to different proposed patterns for the whole day. We will briefly discuss the statistical output from the analysis for the time window of 1400 hours to 1448 hours. We chose the following graph to report the outcome of the experiment. **Fig.2** is the output of pattern 1A as described in **Table 3**.

We observe in **Fig.2** that most of the trip time data are close to each other. Trip time data is the travel time required for each trip for the probe and simulation data as well.

The root mean square error (RMSE) defined by equations (1) is used to judge the proficiency:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \hat{x}_i)^2} \quad \text{...........} \quad (1)$$

where N is the total number of testing cases, $\hat{x}_i$ the predicted simulation trip time and x_i the probe trip time.

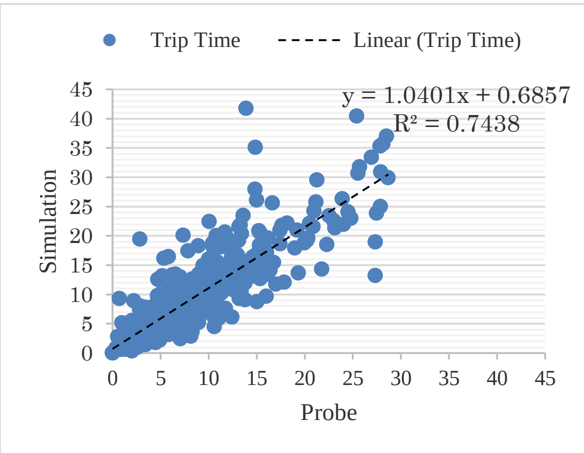

Fig.2 Travel time for different Trips (Minutes)

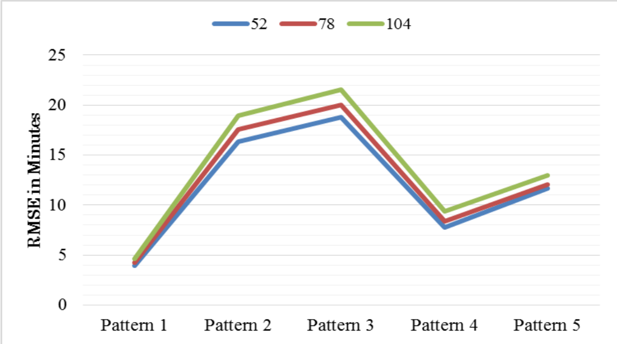

Fig.3 Variations of RMSE (Minutes)

In **Fig.3**, we find the prediction for Pattern 1 and Pattern 4 are better than any other patterns. We can conclude that, pattern 1A as in **Table 3** can be the most preferable pattern to develop the simulation.

5. CONCLUSION

This study has simulated the returning home commuters in different patterns and compared the travel time with the actual movement of the probe vehicle during the downpour.

From the results, pattern 1A is the most preferable pattern to prepare the simulation. From the simulation we can perceive that, the central Nagoya and the roads with bridges and tunnels were the most congested. Our future work will focus on how to use this simulation for forecasting the travel time for commuters simply by adjusting the severity of downpour.

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