Planning of Bus Transportation by Using Traffic Simulation

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Abstract

In a large-scale event as like The National Sports Festival, which is the Japan's largest national sports meet, many people (athletes, invited guest, spectators, committee, etc.,) gather at an event site. Since many people have to be carried to the event venue, it is necessary that transportation is planned in consideration of traffic influence and management of time schedule. In this paper, through traffic simulation, transit plan by using scheduled buses is tested.

Keywords: multiagent system, traffic simulation, transportation planning

Introduction

In this paper, we try to show possibility of utilizing traffic simulation to evaluate transportation plan for big events by exhaustive framework of large-scale simulation. In a big event, design of transportation plan is a critical issue for smooth and feasible operation of the event. Especially, when the event is held inside of city area, the design is so difficult because the background traffics are varied by situations and also affected by transportation for the event. Our purpose is to attach such difficulty with utilizing exhaustive

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simulation to evaluate various situations on high performance computing. As an example of experiments, we apply our methodology to bus-transportation plan in the Japanese National Sports Festival (NFS). NFS is the Japan's largest national sports meet. The Festival has been held every year with prefectures competing against one another, with prefectures hosting the festival in succession (Jpan Sports Association). In an opening ceremony, tens thousands people including spectators, team members, ceremony performers gather in the sports stadium. At holding of such a big event, traffic of the major road to stadium and around parking increase by concentration of participants.

In Wakayama NFS 2015, traffic analysis is carried out beforehand, and transportation schedule of the participant is planned based on it. Effect of traffic must be considered, because it is necessary to carry many participants who are players, viewers, ceremony performers and invited guests to stadium from each staying hotel or parking area by using a large number of chartered buses and public transport. However, Since each prefectures is hosted in relays in spite of the fact that NFS is held every year, it is difficult of host prefecture to utilize obtained knowledge in previous NFS. For such as above concern, the traffic simulator is effective tool in examining prediction and measures of traffic jam beforehand.

This paper report verification for bus transportation plan by using traffic simulator (MATES) through experiment of various situations by high performance computing.

Bus Transportation Plan

Figure 1 show map around stadium, star mark $\star$ indicates stadium, and, bold line and double line indicate express highway and main ordinary road in Wakayama city respectively. More than $20,000$ people come to stadium and about 80% of them transit by bus and it is necessary for participants to enter stadium before entrance is closed.

Figure 1. map around stadium(©OpenStreetMap)

Table1 shows an example of scheduled bus.

Table 1
an example of scheduled bus

group	*num.*	schedule	route	depart	arrive	parking
executive committee member	50	prefectural government building	Kencho-mae → Route 42	6:15	6:45	Okuwa

Figure2 shows parkings around stadium. Due to the limited space in the parking of a stadium(⋆), scheduled buses go to parking area (•) near stadium, and participants walk to stadium.

Figure 2. parking area

Traffic Simulator: MATES

This paper employs traffic simulator MATES (Multi-Agent-based Traffic and Environment Simulator) (H. Fujii, 2011,Yoshimura, 2006). It defines a car as an agent. MATES is composed of lane, crossroad and signal defined as object, and car agent which perceive them and perform automatically. In this paper, simulation is executed as given route and departure time of scheduled bus, estimated OD traffic volume, and ratio of estimated OD traffic volume.

Scheduled Bus Data

Scheduled bus data as input file is described based on draft plan (Wakayam Prefecture, 2015). Input file is described list of departure time and route of buss.

Network map

As shown Figure 1, simulation run based on shown area. Data from OpenStreetMap (OSM) is converted into road network data for MATES as shown Figure 3. Map space in

MATES is represented by the graph structure that deal with an intersection as a node and a single path as a link. MATES load this map and run a simulation based on that.

Figure 3. road network

Deprture points located in Figure 3 are remained in map, aother points are set on terminal of network on defined route and departure time is modified as appearance time.

Estimation of Origin-Destination matrices

In order to predict and measure operation scheduled bus in traffic environment as real world, not only road network but also effect of traffic flow are simulated adequately. For representation of traffic flow, each Origin-Destination (OD) traffic volume are necessary, however, OD traffic volume can not be observed directly. In this paper, OD traffic volume is estimated from data of road traffic census in 2005.

Some estimation method for OD traffic volume is studied (Kitamura, 1996,S. Bera, 2011). This paper adopt method that estimated generated traffic volume and congested traffic volume at each terminals of network are assigned to OD traffic volume by using the gravity model. As number of terminal nodes represent n, number of variables to be estimated is number of combination of termina nodes (i.e., $O(n^2)$). But by dividing of number of variables to be estimated to generated traffic volume and congested traffic volume, number of variables is reduced to $O(n)$.

The gravity model is used extensively for estimation of OD matrices(ex. (Robillard, 1975, Yasunori Iida, 1986)). OD matrices is derived by using following equation (1) based on forgiven generated traffic volume and congested traffic volume.

$$T_{ij} = kG_i^{\alpha} A_j^{\beta} f(D_{ij}) \quad (1)$$

Note that T_{ij} indicates OD traffic volume from departure point i to arrive point j in target network, G_i indicates generated traffic volume in i, A_j indicates congested traffic volume in

j, function $f(D_{ij})$ indicates drag based D_{ij}. For example, equation $f(D_{ij}) = D_{ij}^{\gamma}(\gamma \leq 0))$ is used. k, α, β, γ are arbitrary parameters. In this paper, each parameters are set as follows: $\alpha = \beta = 1$, $f(D_{ij}) = D_{ij}^{0} = 1$, $k = (\sum_j A_j)^{-1}$, and OD traffic volume T_{ij} is calculated by below equation 2.

$$T_{ij} = G_i \cdot \frac{A_j}{\sum_j A_j} \tag{2}$$

In addition, link traffic volume is calculated by using below equation 3 from generated traffic volume $\boldsymbol{G}$ and congested traffic volume $\boldsymbol{A}$.

$$L_k(\boldsymbol{G}, \boldsymbol{A}) = \sum_{i,j} p_k(i,j) T_{ij} \tag{3}$$

Note that $L_k(\boldsymbol{G}, \boldsymbol{A})$ indicates link traffic volume in link k, $p_k(i,j)$ indicates probability which vehicle pass link k from i to j. Given all vehicle choose shortest path, if there is link k on path from i to k, then $p_k(i,j) = 1$, otherwise $p_k(i,j) = 0$.

By using steepest descent method to minimize $R = \sum_k (\frac{L_k - \hat{L}_k}{\hat{L}_k})^2$ which is difference between $\boldsymbol{L}$ (obtained link traffic volume from estimated OD traffic volume) and $\hat{\boldsymbol{L}}$ (actual observed link traffic volume), generated traffic volume and congested traffic volume are updated iteratively. Figure4 shows result of reproduction of traffic volume between from AM 7:00 to 8:00. Horizontal axis indicates actual observed traffic volume, vertical axis indicates link traffic volume by using equation 3 based on estimated OD traffic volume. Regression coefficient is 1.025, and correlation coefficient is 0.983. Similarly, table 2 summarize result of reproduction of traffic volume between from AM 7:00 to 8:00 at holiday. Since estimated OD Traffic volume is acceptable from these result, simulation adopt that.

Table 2

results of reproduction of traffic with estimated OD matrices at holiday in Wakayama

time slot	correlation coefficient	regression coefficient
AM5:00	0.978	0.944
AM6:00	0.985	0.957
AM7:00	0.983	1.025
AM8:00	0.967	1.022
AM9:00	0.951	1.017
AM10:00	0.902	1.033
AM11:00	0.913	1.027
AM12:00	0.911	1.030

Experiment

Case

As described above, OD traffic volume based on estimated trafic flow is increase or decrease Cncretely, rational parameter of above OD traffic volume r is set 1.0 as a standard.

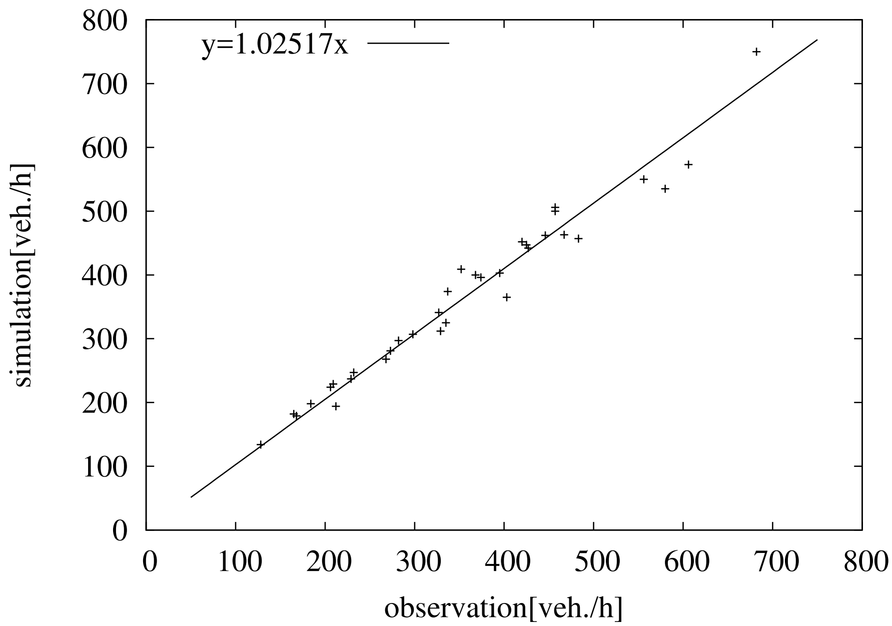

Figure 4. result of reproduction of traffic volume (AM7:00)

In simulation experiment, traffic state is simulated from 5:00 AM to 7:00 AM. Total number of passenger vehicles (i.e., other scheduled bus) on $r = 1.0$ is about 80,000. For example, $r = 0.8$ mean that 0.8 times above standard OD traffic volume is generated. In this paper, 5 cases ($r = 0.8, 0.9, 1.0, 1.1, 1.2$) of simulation are experimented. In order to compare to effectiveness of traffic flow, results of each cases are 100 experiment.

Simulation Job Management

As a job management software for simulation studies, we employ OACIS (Organizing Assistant for Comprehensive and Interactive Simulations)(Y. Murase, 2014). An overview of the system is depicted in Figure5.

The kernel of the system is developed based on Ruby on Rails framework (http://rubyonrails.org/) and internally adopts MongoDB (http://www.mongodb.org/). OACIS has a web browser interface, and users can find simulation result, progress status. Once jobs are submitted, OACIS periodically checks if the jobs are finished, and after these jobs finished, OACIS downloads the result files and store these in a file system in a traceable way.

Simulation Result

Figure 6–10 show simulation results. In each figure 6, 7, 8, 9, and 10, vertical axis indicates arrival time, horizontal axis indicates buses ordered by scheduled arrival time, respectively. From each results, almost buses arrived early, and arrived times are little difference between each cases. As shown 6 and figure7, since buses that scheduled arrival time is before 9:00 AM start at early morning, traffic volume is small and effectiveness of parameter r is small. As shown 8, 9, and 10, effectiveness of OD traffic flow appear for

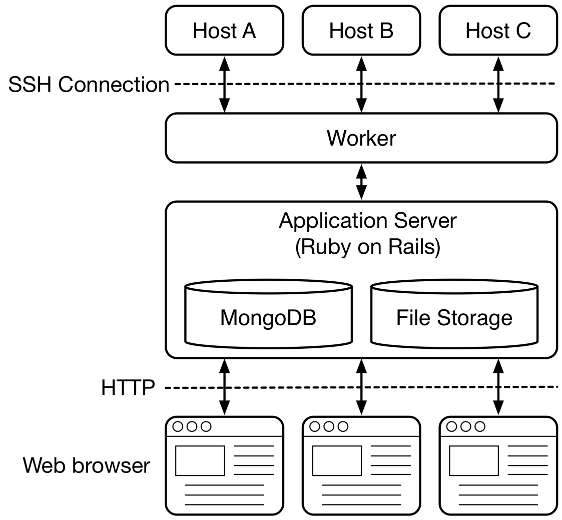

Figure 5. Overview of OACIS

busses which are scheduled arrival time at 9:30 over. Especially, large difference of arrival time between each cases imply effectiveness of traffic congestion in main of wakayama city. For example, right hands in 10 indicate a scheduled bus as above. On the other hand, left hands in 10 indicate a scheduled bus driving on a highway, this bus is less affected from traffic congestion because parking is near from exit of highway.

Even so $r = 1.2$, average of difference between scheduled arrival time and arrived time range ± 15 minutes, and simulation result imply that bus transportation is basically enable to be carried out according plan.

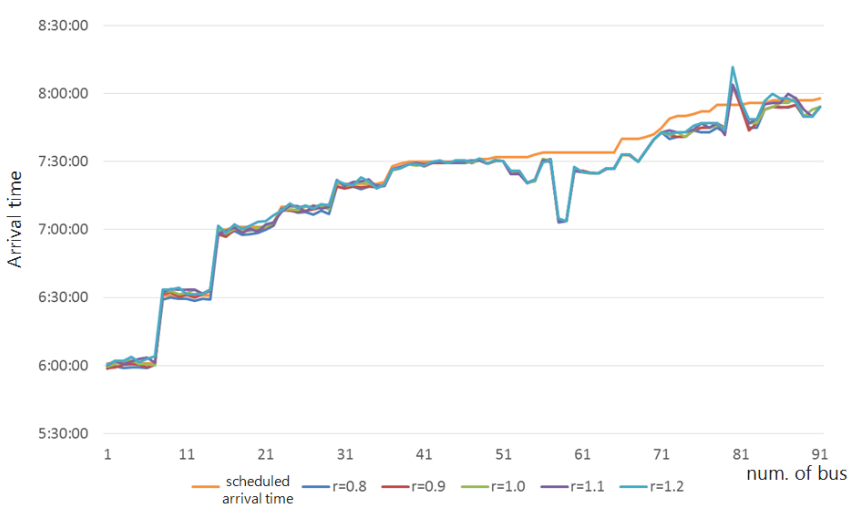

Figure 6. result of bus scheduled arrival time before AM8:00

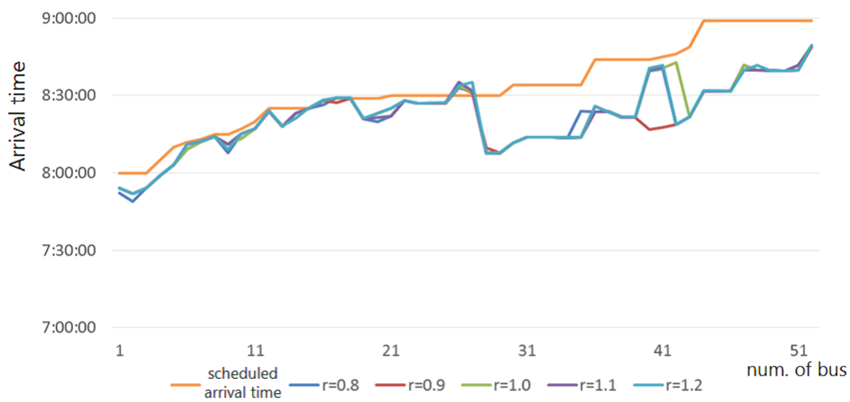

Figure 7. result of bus scheduled arrival time between AM8:00-9:00

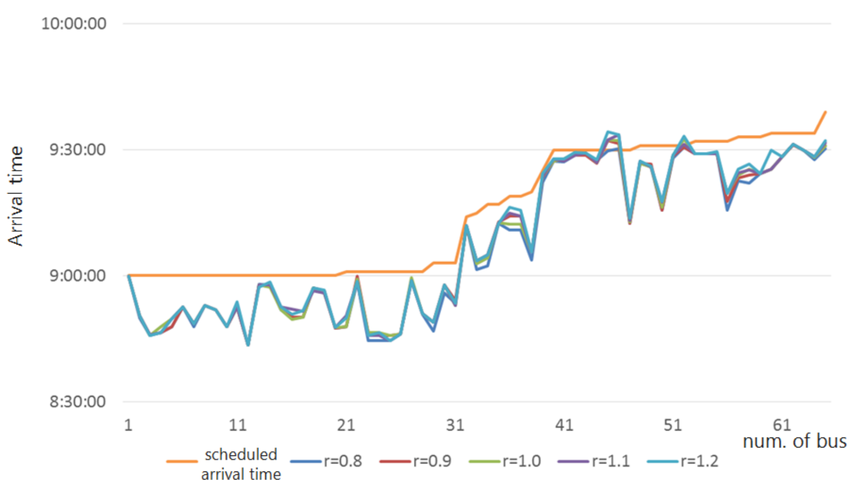

Figure 8. result of bus scheduled arrival time between AM9:00-10:00

Conclusion

In this paper, we try to show possibility of utilizing traffic simulation to evaluate transportation plan for big events by exhaustive framework of large-scale simulation. By using traffic simulator MATES, OD traffic volume is estimated and scheduled bus transportation in opening ceremony of NFS is evaluated. By changing proportion of estimated OD traffic volume, influence for scheduled bus transportation is evaluated. From simulation result, buses started at early morning or through highway are affected by traffic congestion. On the other hands, buses through center of wakayama city are easily to be affected by increasing traffic volume. In order to reduce occurrence of traffic congestion, staff of transportation plan of NFS address to announce from some media and ask for companie's corporation that have large vehicles. These efforts lead to success of transportation according to plan smoothly.

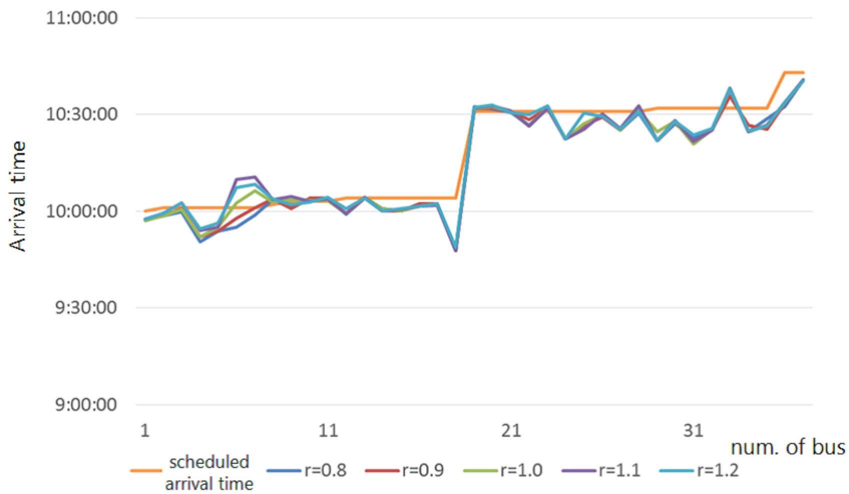

Figure 9. result of bus scheduled arrival time between AM10:00-11:00

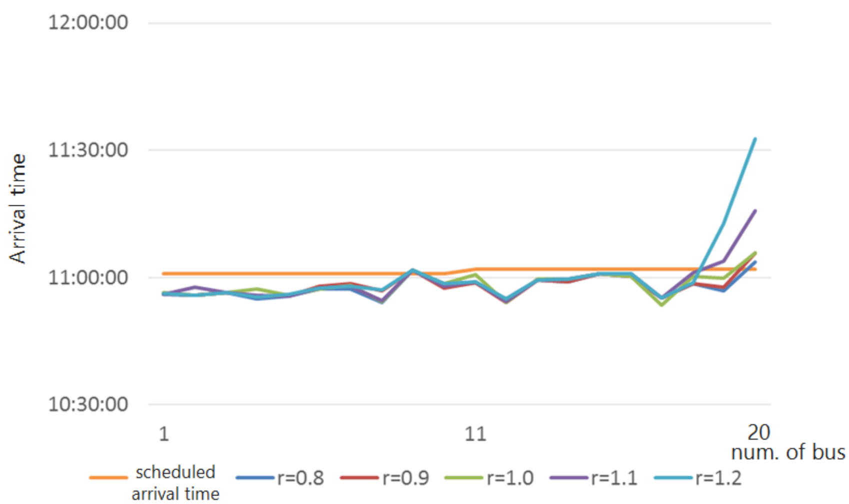

Figure 10. result of bus scheduled arrival time after AM11:00

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