A traffic simulation model of pedestrian and vehicle for evacuation under natural disaster

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ABSTRACT

In this study, we developed a traffic simulation framework of pedestrian and vehicle to evaluate the evacuation plans under natural disasters. In this paper, we introduce the concept of our framework and explain the traffic model and the road crossing behavior model of pedestrian and vehicle in the simulation. This framework has a function to be attached the disaster event model (link closing and lane closing). And the evacuation behavior model can be installed depending on the purpose of the evaluation of evacuation measure. As the future work, we have a plan to apply this framework to urban city and describe the results of some evacuation plans.

Keywords: Traffic Simulation, Pedestrian, Vehicle, Evacuation, Natural disaster

1. INTRODUCTION

In Japan, many researches of evacuation plan under natural disaster are studied on the background of our experiences such as the Great East Japan Earthquake and the Great

Hanshin Earthquake. Oshima et al.[1] evaluated the traffic measures to reduce the congestion in Tokyo on the day of the Great East Japan Earthquake. Erick et al.[2] and Innami et al.[3] installed Tsunami event model to their traffic simulation model and simulated the evacuation of vehicles and pedestrians. In the case of traffic simulation study, it is said that the behavior models of vehicle and pedestrian under disaster have been implemented in a traffic simulation model in recent years. However, the knowledge about the understanding of the traffic situation by disaster and the effective evacuation plan for large area (the whole of city) are far from accumulated. For example, the latescent bottleneck point when the people evacuate from natural disaster by vehicle or by walk should be understand. In this case, the traffic demands for evacuation from natural disaster should be included not only the vehicles on the road network but also the people in buildings, homes, traffic facilities and so on. On the other hand, the impassable roads by fired and collapsed buildings and the heavy congestion of vehicles and pedestrians by the concentrated inbound traffic should be considered when we make the evacuate plan to guide the people to the safety places. To understand these issues, the traffic simulation model which can dynamically reproduce the traffic condition (especially queue spillback, capacity reduction and grid lock) by natural disaster is needed. And it is important that the conflicting of vehicles and pedestrians is one of the needs to express the disruption of the traffic flow. Therefore, we develop the traffic simulation framework with the conflicting model of pedestrians and vehicles to evaluate the evacuate plan from natural disaster.

2. THE CONCEPT OF SIMULATION FRAMEWORK

Our traffic simulation framework is developed to reproduce various traffic situations on road traffic under natural disaster and to evaluate the effects of evacuation measures. The framework has the following concepts.

- Dynamic traffic simulation model for the region-wide road network (10 or 20 square km, up to 10000 links).
- Layered road network structure for several kinds of traffic modes.
- Interactive modelling between pedestrian and vehicle (link capacity reduction by the crossing behavior of pedestrian and vehicle).
- Including route choice behavior with many-to-many OD of pedestrian and vehicle.
- Disaster event model (link closure event, lane closure event, destination change event, etc.)

Figure 1 shows the traffic simulation framework. The framework consists of the traffic simulation model integrated pedestrian model and traffic flow model, the disaster event model and the evacuation behavior model. The traffic simulation model includes the crossing behavior model and the interfaces to accept the event requests from the disaster event model and the evacuation behavior model.
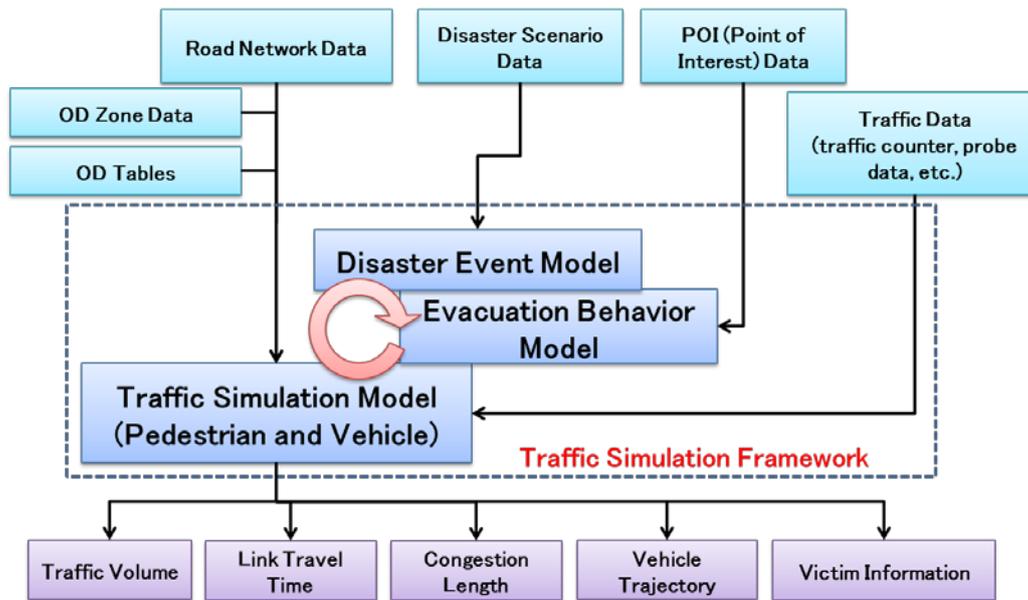
Figure 1 : **Simulation Framework**

3. TRAFFIC FLOW MODEL AND PEDESTRIAN MODEL

In this section, we introduce the traffic flow model and the pedestrian model. For the traffic flow model, we prepared the traffic simulation model SOUND (a Simulation model On Urban road Networks with Dynamic route choice)[4]. The vehicles in SOUND is discretely moved based on the Newell's simplified kinematic wave model[5][6] and can be controlled by traffic signal and the link parameters (link capacity, jam density, free travel speed, saturation flow rate, number of lane, etc.). SOUND has two types of route choice model (minimum cost choice model and logit choice model based on Dial's algorithm). On the other hand, the pedestrian model has a simple moving model by the constant speed controlled by the density (number of person) of link referred to Fundamental Diagram (K-V relationship). The pedestrian model is also installed the same route choice mode l as SOUND.
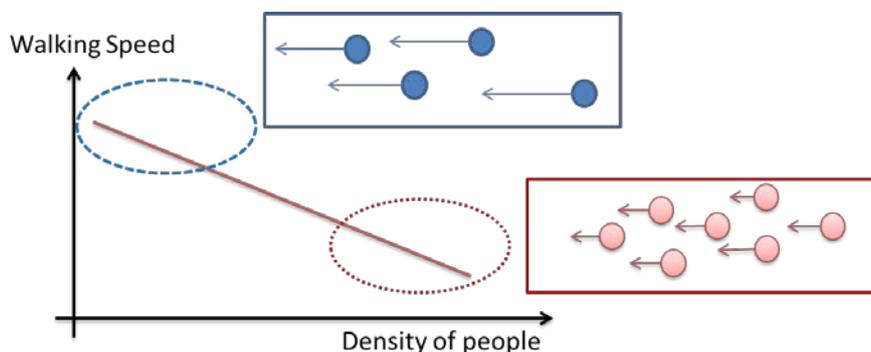
Figure 2: **Basic Idea of the pedestrian model**

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Figure 3 and Figure 4 shows the interactive points between vehicle road network and pedestrian network. The traffic flow model and the pedestrian model share some crossing points on each road network. And the vehicle on the vehicle's road network performs the stop-and-go behaviour when the pedestrian on the crossing point.
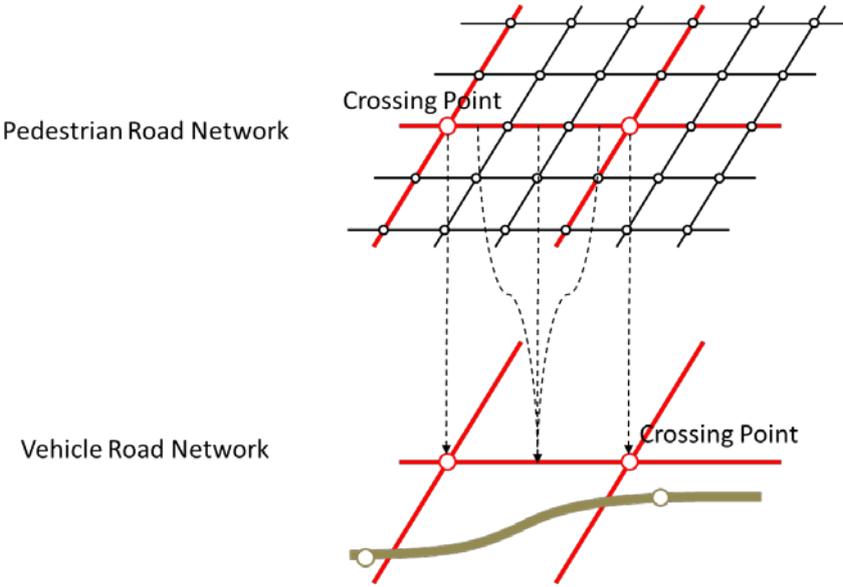
Figure 3: Interactive points on road network
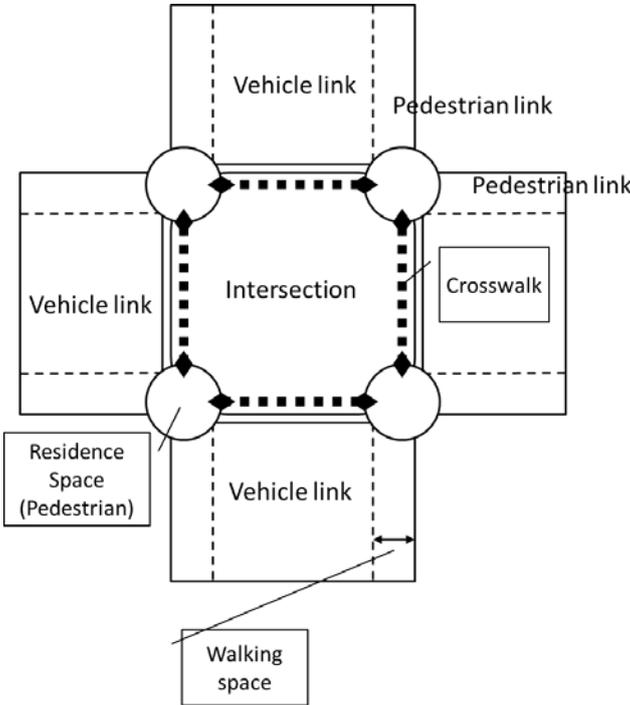
Figure 4: Network structure and crossing behaviour in an intersection

4. INPUT DATA FOR SIMULATION

The basic input data for the simulation framework consist of the road network data, zone data and OD table data (time series for each vehicle/person type). In addition, the disaster event data such as link closure event (the set of event time, closing link id) and the evacuation behavior data (new OD table and Destination data for evacuation) are needed for the disaster simulation. The new destination data for evacuation can be used the location data of the evacuation place such as school and park. Figure 5 shows the example of network data and zone data, and Figure 6 shows the example of POI map data.
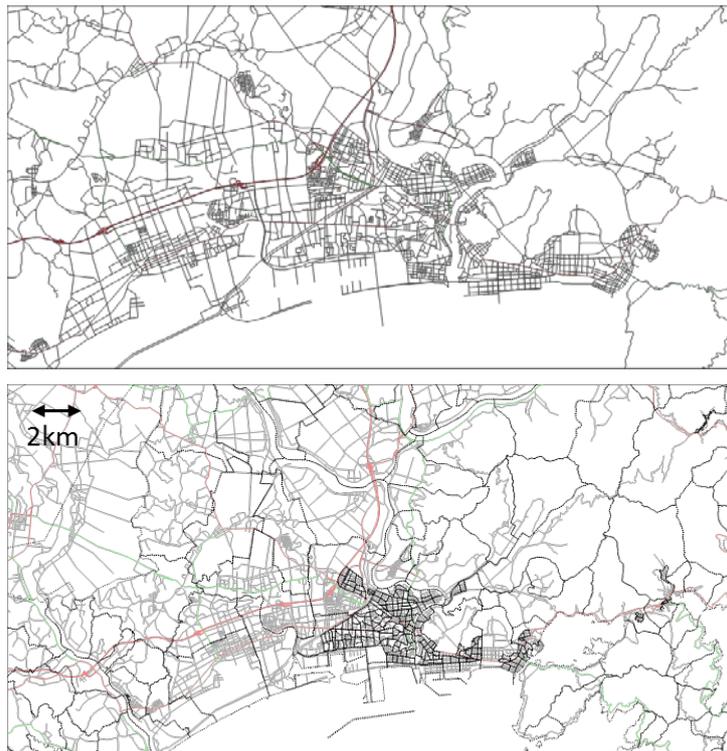
Figure 5: Road network data and zone data
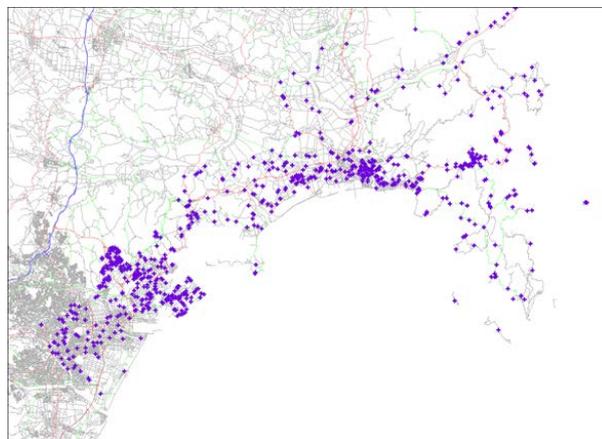
Figure 6: Example of POI data (evacuation place)

5. CONFLICTION BEHAVIOR MODEL

In this study, two basic models to express the confliction behaviours between vehicles and pedestrians are implemented. Figure 7 shows the concept of the confliction behaviours model. The crossing model has a function that vehicle is stopped when pedestrian is existed (walking) on the crossing point of vehicle's road and pedestrian's road. On the other hand, the capacity reduction model has a function that the capacity of vehicle's road (link) is reduced when the density of pedestrian's road (link) is high (one of simulation parameters). This situation by the capacity reduction model is assumed the flooding of pedestrian by the concentrated to the public space such as train station.
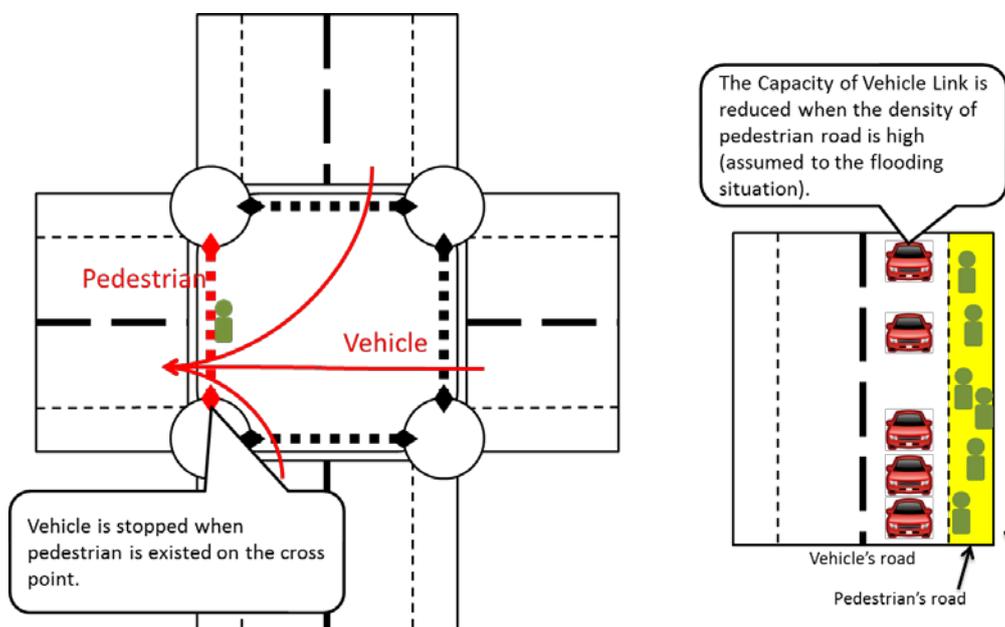
Figure 7: Confliction Behaviour Model

6. EVACUATION MODEL

The traffic impact by the evacuation behavior can be reproduced by the destination change behavior model and the departure selection model (determination of start or stop trip) for the vehicle and the person which is planned to departure before the disaster event occur. If the vehicles or the persons running on the road network is caught in the disaster (link closure event) such as tsunami, they are stopped the trip and counted up as the result of victims by the disaster. Figure 8 shows the image of the disaster event model and the evacuation behaviors in our simulation framework.
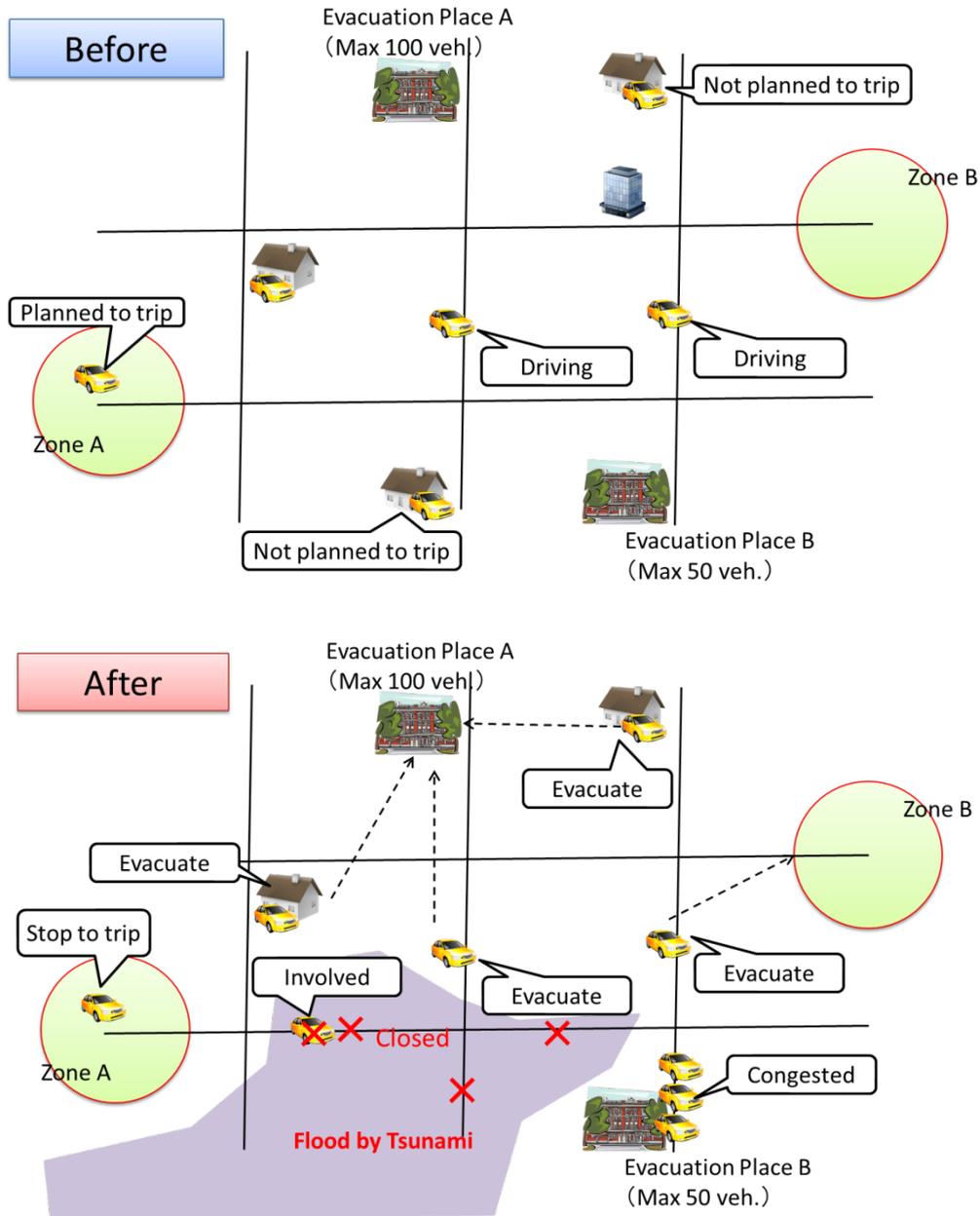
Figure 8: Example of Disaster Event and Evacuation behaviours

7. EFFECT OF CONFLICTION OF VEHICLES AND PEDESTRIANS

Figure 9 shows the calculation result of the effect to vehicle traffic by pedestrian traffic in an intersection (Jimbocho-intersection) in Tokyo. In this case study, we verified the reduction pattern of the capacity of vehicle traffic by the traffic of pedestrian. The traffic volumes of vehicle from each direction and the signal timing data are surveyed at peak time from 9:00 to 10:00. The simulation is calculated with shifting the traffic volume of pedestrian through the intersection. The conflicting behavior (crossing of vehicles and pedestrians) model and the capacity reduction model (vehicle's road) by the pedestrian's flooding to the vehicle's road are implemented. The traffic volume and the average speed of vehicle are declined drastically

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in case of over 2000 (pedestrian traffic). The models will be validated and improved comparing to the real data as a future work.
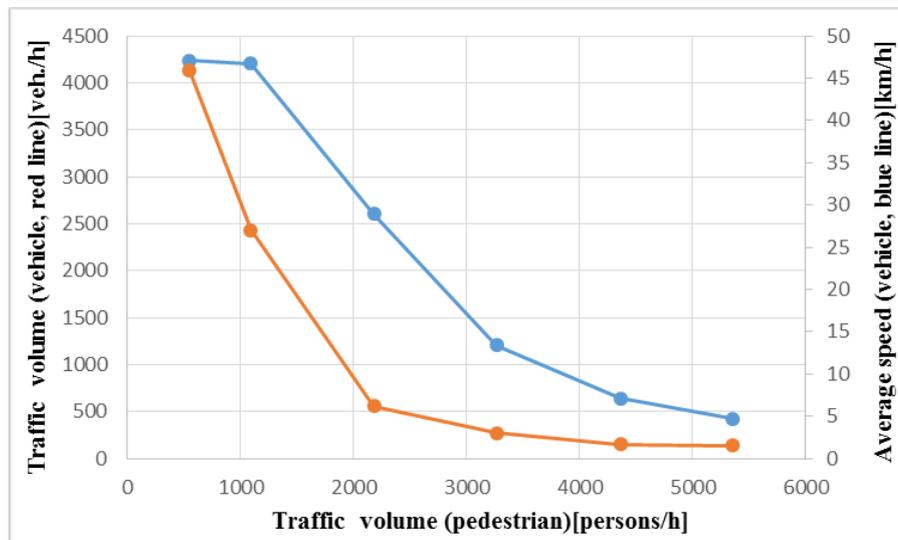
Figure 9: **Effect to Vehicle Traffic by Pedestrian in an Intersection**

8. FUTURE WORK

For the next step, our simulation framework will be verified using the verification manual for traffic simulation model with disaster and evacuation model by Japan Association for Earthquake Engineering[7] (JAEE) before the application to case study. JAEE offers the five outputs (vehicle/pedestrian generation, moving speed, route choice, impact of traffic flow by escape route and congested situation) for verification and three outputs (network data and od volume data of validation area, simulation result) for validation to describe.

And we have a plan to evaluate evacuation plans for the 23 words in Tokyo using our framework. Figure 10 shows the target area. The traffic situation in disaster is calibrated by using the detector data and the probe data in the day of the Great East Japan Earthquake with some disaster event model based on the hazard map in Tokyo (link closure events and lane closure events).

Figure 10: **Target network for evaluation (Tokyo 23 words)**

9. ACKNOWLEDGEMENT

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