Ⅳ-27 An Approach to Evacuation System Modeling and Assessment - II

Evacuation Time and Traffic Delay estimation to improve evacuation plan and infrastructure

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1. INTRODUCTION

This is the second part of a 2 part paper. Part-II, this paper, concerns development of a procedure for study of evacuation plan and infra-structure capability to meet the requirements during an emergency evacuation. In part-I we discussed GIS database development and assignment of resident-evacuation center.

Many researchers have studied the process of evacuation system assessment in the past. Evacuation time estimates, sometimes also referred as clearance time, is generally used as a measure of effectiveness[2),3),4)]. Simply it is the time duration between evacuation order issue and last person reaching safety. Disasters such as nuclear discharge, chemical release, dam failure flooding affects wide area and researchers have used car to simulate evacuation in such cases[2),3)]. Walking is used to simulate evacuation of smaller areas. Takahashi et.al has simulated evacuation by walk for Ogura basin embankment failure and Kami-furano town mud-flow disaster.

Most researchers have used elaborate routing and traffic calculation techniques in the simulation models. However, input data has been aggregated to courser resolution, perhaps to overcome computational and data management problems. For example, Takahashi et.al have considered only 141 road links in their Kami-furano town simulation, while there are roughly 9000 road links. From a consultant's viewpoint, assessment of town's evacuation system will require higher input resolution. Computational load was reduced by dividing the model into many separate modules. Data preparation and management tasks were simplified using GIS system.

2. EVACUATION SYSTEM ASSESMENT / IMPROVEMENT

Evacuation is an unsteady process where flow in road-links changes dynamically (see figure-1) influencing the link's travel-time. Simulation was used to estimate the evacuation time. We calculated two types of evacuation times in our assessment instead of just one, namely Simplified Evacuation time (SET) and Estimated Evacuation Time (EET), and is schematically explained in figure-2. EET, calculated considering traffic capacity limitation, gives a measure of distance between residents and evacuation centers during emergency. Traffic delay time, which is difference of EET and SET, gives a measure of delay due to inadequate infra-structure.

Just evacuation time alone doesn't provide sufficient information on evacuation infra-structure. For example, a large evacuation time may mean that the residents are far away from evacuation centers or alternatively may mean high traffic delay because of poor evacuation infra-structure. EET and Traffic delay time give a better idea.

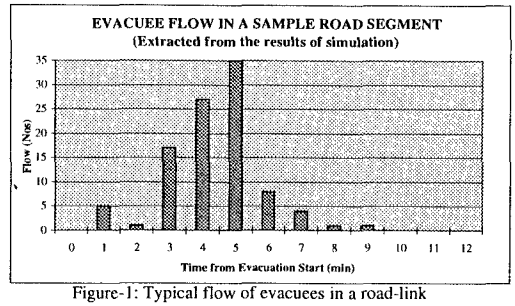

Figure-1: Typical flow of evacuees in a road-link

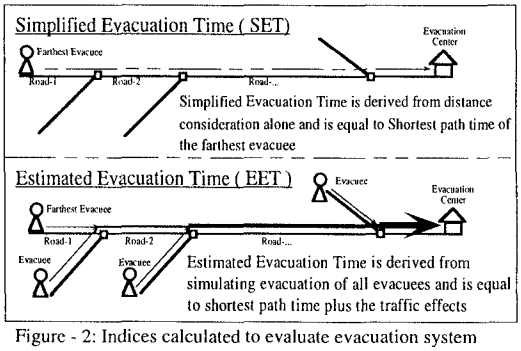

Figure - 2: Indices calculated to evaluate evacuation system

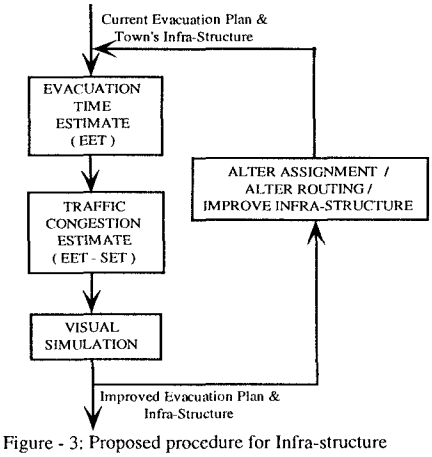

Figure - 3: Proposed procedure for Infra-structure Assesment and Improvement

Assessment of the evacuation plan using EET and Traffic Delay Time is schematically explained in figure-3. A GIS system based visual simulation program was developed to study where and how congestion takes place. Overall evacuation plan can be improved by altering assignments, routing and infra-structure.

3. CASE STUDY

Study focused on assessment of Kami-furano town's evacuation system. Mud-flow disaster is expected to occur in furano river and inundate the Kami-furano town upon re-eruption of Mt. Tokachi. Last major eruption occurred in 1926 and mud-flow killed 144 people.

The following scenario was assumed. "All residents in hazardous area are at their houses and will evacuate immediately on receipt of order via shortest route using the transportation advised by the town – walk or car.. Order will be issued through pre-installed wire-less system. When walking, all family members will walk together at 1.4m/s speed and in the case of car, each family will travel in one car. Even though car based evacuation is rare in Japan, considering the spatial distribution of residents and evacuation center in Kami-furano town, car based evacuation was also considered.

Two case study is presented here for discussion

Case-A: Evacuate to the nearest evacuation center.

Case-B: Evacuate to the nearest evacuation center outside hazard area.

The approach we took to model the problem is briefly described below:

(a) Travel-time was considered constant and in case of car, was calculated from the average speed[6]. For walk 1.4m/s speed was used.

(b) Resident-evacuation center assignment was performed so as to minimize the maximum evacuation time.

(c) The route of each resident was identified using shortest path method and SET was calculated.

(d) An evacuation simulation program was developed to simulate the evacuation process and calculate EET. Fatigue and crowding were considered for walking as in Takahashi et.al paper[4]. Road capacity limitation was considered for car as stated in Highway capacity manual[5].

(e) An example of visual simulation of roads around "Ohara Jisaki evacuation center" is shown in figure-4. Congested areas can be identified using visual simulation. Assignment, routing and road-infrastructure alteration can be studied to improve the overall evacuation system.

Table-1: Summary of EET and Traffic Delay in minutes.

Case Number	Evacuation Times		Traffic
	SET	EET	Delay Time
Case-A-Walk	0:27	0:27	0:00
Case-A-Car	0:04	0:06	0:02
Case-B-Walk	0:33	0:33	0:00
Case-B-Car	0:05	0:20	0:15

4. CONCLUSION

Result is summarized in table-1 for two cases. Considering case-A-Walk, EET is 27min and Traffic delay time is insignificant. This shows fairly sound road infra-structure. However residents and evacuation centers are wide apart. Considering case-B-Car, EET is 21min but 15min is due to inadequate infra-structure. Evacuation time can be improved by improving on evacuation plan or road infra-structure.

Even though this procedure was applied to mud-flow disaster problem, we can apply it to asses other evacuation systems. Further it is possible to compare the evacuation infra-structure of various towns, using EET and traffic delay time, for a given type of disaster.

5. ACKNOWLEDGEMENT

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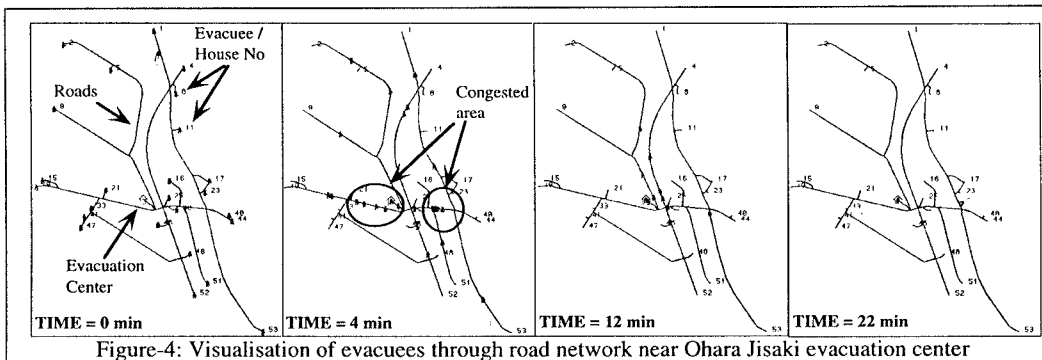

Figure-4: Visualisation of evacuees through road network near Ohara Jisaki evacuation center