Construction of Preliminary ETE Model Using TSIS-CORSIM

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1. Introduction

Evacuation Time Estimate (ETE) is to calculate the time for public resided in EPZ (Emergency Planning Zone) to evacuate outside of the EPZ. ETE is important for a decision of public protection measures, such as evacuation and sheltering-in-place, from radiation emergency. Using the results of the ETE analysis, the protection measures could be determined flexibly, such as scope and direction of the measure, notification time, staged evacuation and etc., when an accident actually occurs. In addition, the results of ETE are needed for emergency response model in Level 3 PSA (Probabilistic Safety Assessment). The inputs used in the ETE model should be the same as the inputs of the emergency response model in Level 3 PSA, and some results of the ETE analysis might be the inputs in the emergency response model.

In the US, ETE is part of the planning basis for each nuclear power plant, and as such, ETE is required to be performed by licensees to estimate the time needed to evacuate the public in the unlikely event of a serious accident. Likewise, in Korea, it is required to perform ETE through consultation with local autonomous entities and to attach its results to emergency preparedness plan as a document.

The purpose of this study is to construct a preliminary ETE model by reviewing the methodology used in the US and to identify and present various limitations and constraints in constructing the ETE model in Korea.

2. Methods and Results

In this section, the procedure for ETE is described and each step of the procedure are briefly introduced. The procedure of ETE is demonstrated briefly in Fig. 1.

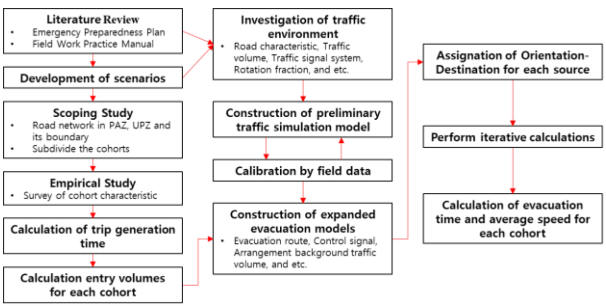

Fig. 1. Procedure of ETE analysis

2.1 Literature Review

The first step is to review the emergency preparedness plan and the manual of fieldwork practice documented by the local autonomous entity. The documents include the plan of public protection measures, access controls on major roads, and traffic control plans. In particular, evacuation routes, assembly areas, support centers, and available transportations for each village are described in detail[1,2].

2.2 Development of Scenarios

Evacuation scenarios should be developed to identify combinations of variables and events to provide ETEs under varying conditions to support protective action decisions. Scenarios could be determined by season, a day of the week, time of day, weather conditions, and special events to attract people, roadway impact, or other circumstances that should be assessed. Multiple scenarios are intended to ensure that the ETE results encompass a reasonable range of potential evacuation situations for the specific site[3]. In this study, four scenario was determined as follow.

Scenario 1: Summer, Midweek, Daytime, Normal Weather
Scenario 2: Summer, Midweek, Evening, Normal Weather
Scenario 3: Summer, Weekend, Daytime, Normal Weather
Scenario 4: Fall, Weekend, Evening, Normal Weather

2.3 Scoping Study and Empirical Study

The scoping study and empirical study are the foundation of the ETE analysis. In order to determine the scope of the ETE study, it is essential to clear the area, people, means, routes, and time.

The ETE model should be developed based on the EPZ. After the Fukushima accident, the EPZ in Korea was subdivided into PAZ (Precautionary Action Zone) and UPZ (Urgent Protective action planning Zone) to ensure the effectiveness and flexibility of the protective measures. Hence, it is important to classify which villages in the PAZ or UPZ belong to which administrative districts and under what kinds of control by government.

The public includes all persons within the EPZ, including residents, transients, those with disabilities and those with access and functional needs, and any other member of the public. Demographic data, including information and assumptions on population groups, could support an estimate of the public and corresponding vehicles that will be evacuating the area[3].

And, there are shadow evacuation and special events as other considerations. When considering them, it is important to avoid double counting of the public.

In order to obtain time distributions, a questionnaire, one of the empirical study techniques, should be conducted for the public. Through the time distribution obtained by the questionnaire, it is possible to calculate the time until a person receiving the notification gets to the road.

Even if they belong to the same group, the place may be different at the time of notification. This point is very important and uncertain. Therefore, the contents of the questionnaire should include the location where a person takes notification, the action steps, as detailed as possible, that presented separately, and the time required for each step. The time of each step is stochastically multiplied to generate the TGT (Trip Generation Time) distributions, which is shown in Fig. 2. Then, the entry volume is determined by vehicle counts and the distribution.

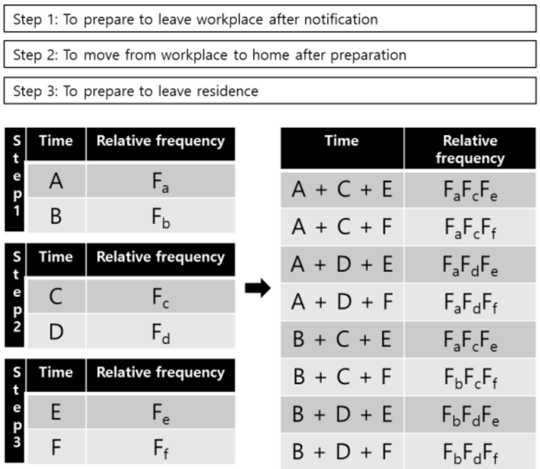

Fig. 2. Simplified example to calculate trip generation time

After identifying the characteristics of all population groups, different time intervals and steps should be presented for each group. Because the finer the time interval is divided, the more reliable the data is.

2.4 Construction of ETE model

It is required to construct input data of traffic simulation code after the detailed review and data acquisition of the emergency preparedness plan. It is needed to obtain traffic volumes, signal cycles, rotation fraction on intersections, road structure and other information. This information can be obtained through the department of transportation or field surveys.

2.4.1 TSIS-CORSIM

TSIS-CORSIM (Traffic Software Integrated System-CORidor-microscopic SIMulation program) consists of an integrated set of two microscopic simulation models that represent the entire traffic environment. The freeway sections can be modeled by FRESIM, the urban subnetwork can be modeled NETSIM. The following figures illustrates a multiple-model network [4].

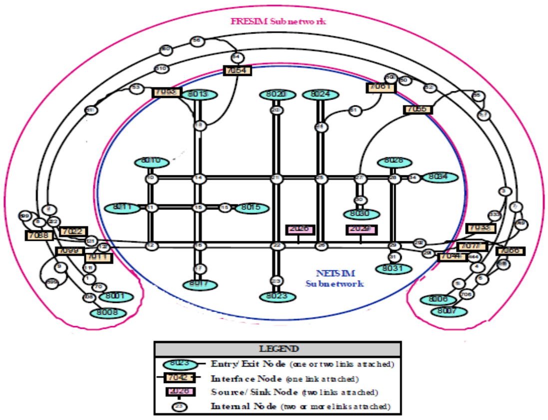

Fig. 3. Multiple model network

CORSIM applies time step simulation to describe traffic operations. Each vehicle is a distinct object that is moved every second. Each time a vehicle is moved, its position (both lateral and longitudinal) on the link and its relationship to other vehicles nearby are recalculated, as are its speed, acceleration, and status. And, CORSIM is a stochastic model, which means that random numbers are assigned to driver and vehicle characteristics and to decision-making processes. MOE (Measure Of Effectiveness) that is obtained from the simulation is the result of a specific set of random number seeds.

2.4.2 Construction of Preliminary Model

The following steps are the basic process for using TSIS-CORISM for analyzing an existing traffic network [5].

1. Determine the network geometry
2. Obtain traffic and signal data
3. Build a link-node model of the network using TRAFED, TSIS-Next, a third-party pre-processor application, or a Text Editor
4. Run the simulation using CORSIM
5. View the animation in TRAFVU to verify the inputs and confirm vehicle movement and signal operations
6. Use the CORSIM tool's multi-run capability or use the TSIS Multi-Run Same Case script to perform multiple CORSIM simulations of the network using different random number seeds
7. Examine the distribution of relevant MOEs and compare with field data
8. Adjust calibration parameters as needed to match field data as closely as possible
9. Go back to step 7 and repeat the process until CORSIM results and field data match reasonably well

The duration can be roughly divided into two parts as follows. First, it is an equilibrium state for each scenario. In another word, the traffic environment information for each scenario is reflected in order to reach the equilibrium state of each scenario. When the equilibrium state is reached, the inflow and outflow of the vehicle will become constant in the total network. However, the inflow and outflow can be different from the observed values because not all roads inside the EPZ are modeled. Therefore, additional road network modeling is required to obtain values close to the observations. After selecting some links on the network, the appropriateness of the model could be verified by comparing the simulated traffic volume with the observation.

Second, it is a period during the time when evacuees are notified and evacuees get to the road based on the rate of road inflows made up of various distributions. It should also reflect the traffic control plans over time. It is recommended that traffic control is modeled from near the nuclear power plant to the boundary of EPZ by adjusting the fraction of rotation on the intersection and adjusting the signal control.

The periods and its description are presented in Fig. 4. When constructing the ETE network model using CORSIM, the periods must be specified. The characteristics of each period and the distribution of sources are presented. In addition, classification of population groups in PAZ is presented in Fig. 4.

The network model developed in this study is shown in Fig. 5. When constructing a road network, the road selection criteria is needed. The criteria are highways around the reference plant, high-traffic national roads, and public roads. Road network modeling is based on links and nodes, and new nodes are inserted where link information changes. However, when the number of links and nodes increases, various problems arise. For example, it is difficult to modify the model easily and quickly because of the features of the program. And, another problem arises. In order to reflect evacuation routes, it is required a process of grouping links corresponding to the routes by each source as a sing link. In the process, it is hard to group the links because of many links.

There is another important consideration. It is a calculation of the rotation fraction of the ramp node entering the highway. The factor that determines the rotation fraction of the ramp node is the ratio of the sources that enter the ramp node. The ratio should be calculated by classifying the evacuation routes of each source.

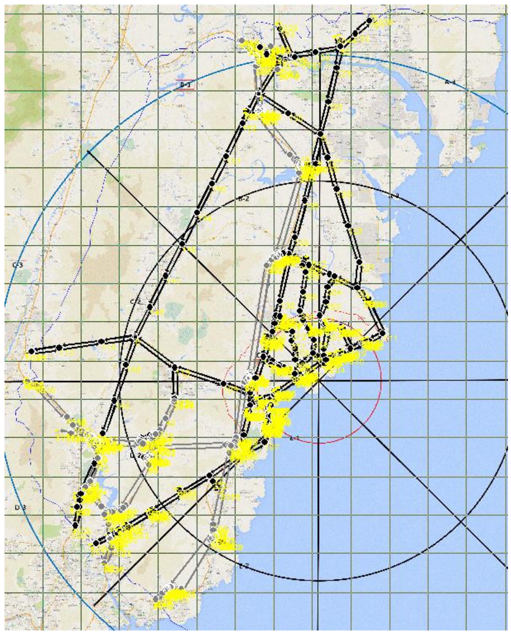

Fig. 5. Preliminary Network Model by TSIS-CORISM

2.5 Results and Future Work

The characteristics of the preliminary model can be summarized as follows. First, normal traffic information is reflected for each scenario, and it is possible to simulate the normal traffic situation until the notification occurs. Second, all source data within the PAZ(about 5km) have been completely inputted, and all the vehicles can move outside the PAZ by varying the rotation fraction according to the time period. Third, The background traffic volume within 5km decreases continuously over the period. Fourth, changes in source input and rotation fraction between PAZ and UPZ are not inputted. Also, it is necessary to determine the period in which the traffic control plan will be reflected. Fifth, it is required to group the links corresponding to the evacuation routes. If then, it is possible to calculate every

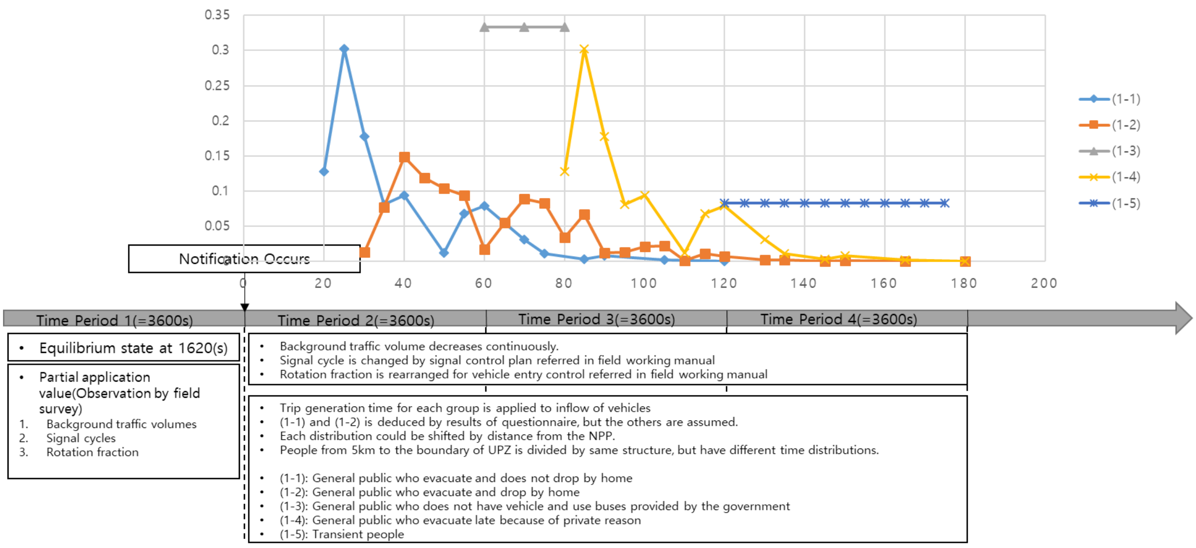

Fig. 4. Preliminary Network Model by TSIS-CORISM

evacuation speed for each source. In addition, pre-classification for each source is required in order to simulate keyhole evacuation as an additional consideration.

Various MOEs including the speed can be produced by TSIS CORSIM. The MOEs can be used for model calibration. In this study, 10 simulations were conducted and the average speed of the entire network, NETSIM, and FRESIM was calculated. The results are shown in Fig. 6 and 7 below.

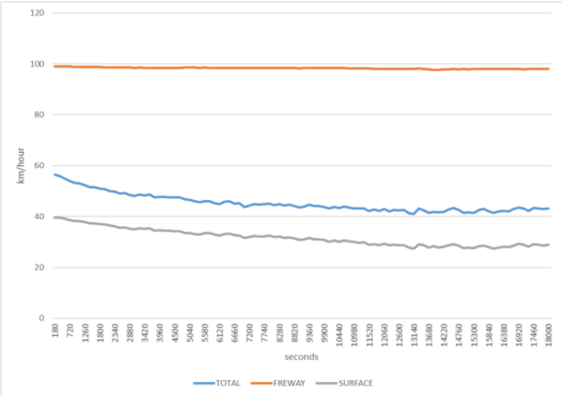

Fig. 6. Average Speed of TOTAL, NETSIM and FRESIM

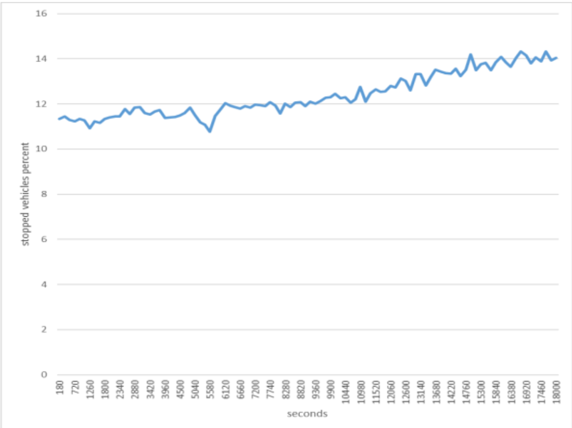

Fig. 7. Stopped Vehicles Percent

The graph of the average speed for the entire road network is shown in Fig. 6. The average speed of the highway is not significantly different from the inputted free volume speed and is kept constant. The average speed of the surface road decreases from about 40km/h to 30km/h and then increases again over the time. The trend of the average speed change of the whole road almost coincides with the national road, and the value is upward. And, it is unrealistic to keep the speed of the highway at about 100km/h. The reason can be found in the following. The negative effects on the moving vehicles around the sink node at the UPZ boundary were not taken into account. Because there is no traffic congestion inward from the outside of the present outermost part. This can be solved by additional modeling.

The graph of the stopped vehicle percent is shown in Fig. 7. It is seen that congested vehicles continue to increase. But it is also not a realistic result. It is not considered applying the negative effect, which is obtained by reducing the background traffic volume outside the PAZ, and the positive effect, which is obtained by adjusting the rotation fraction.

3. Conclusions and limitations

ETE is to calculate the time for public resided in EPZ to evacuate outside of the EPZ. In the US, ETE is part of the planning basis for each nuclear power plant and ETE is generally recognized as important. In addition, various technologies and knowledge to perform ETE have been developed. However, in Korea, it is a fact that the ETE analysis has not been performed properly after EPZ revision. In that regard, this study started to be performed. In order to perform ETE, the methodology of the US was reviewed as a whole and it was applied to this study. And, domestic literature was reviewed in order to reflect its information. And, as a result, it was suggested that the trend of average speed and the stopped vehicle percent.

The preliminary model developed in this study has many limitations. First, the number of scenarios is small. For instance, scenarios involving special events must be developed to ensure the rationality of the ETE results. Second, the source data of the preliminary model was inputted by 'ri'. In order to improve the rationality of the model, it is needed to subdivide the source and reflect it. Third, additional modeling of the EPZ boundary sink node is required in order to reflect traffic congestion from outside the EPZ boundary to the inside. Before additional modeling, a sensitivity analysis should be performed in order to understanding slow-down effect by additional networks.

Acknowledgements

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