Study of Simulation Model for Estimation of Manpower Availability in Radiological Emergency

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1. Introduction

Local governments are preparing an action manual, to be used during disaster management, for radioactive disaster response activities [1]. It is necessary to develop a document classification system beneficial to the support personnel for performing their duties and the methods to predict the number of field personnel. We propose a methodology to implement the local government's resident protection measures implementation support system to accomplish the same.

To predict the number of field personnel for disaster response, a system was developed to calculate the number of field personnel of local governments in the event of a radioactive disaster [2]. Based on the current nuclear power plant safety field action manual, the relations between the variables were mathematically modeled and implementation procedure were developed to calculate the required manpower.

2. Methods and Results

This section describes the techniques to gather the required personnel for emergency response. These are dynamics techniques that include a high-level causal loop diagram, low-level causal loop diagram, and estimation mechanism for optimal manpower. The system dynamics technique identifies issues by observing the shape of the changed object and controls the system through appropriate responses [3].

Various variables can be entered, and feedback can be exchanged as per the causes and results by specifying correlations. In this study, we calculated the number of required personnel by applying the developed technique to the resident evacuation system, which requires analysis of various variables and correlations.

2.1 High-level causal loop diagram

High-level causal loop diagram shows the causes and effects between the number of field personnel and evacuation time.

It is necessary to evacuate the population inhabiting the radiation emergency planning area to establish radioactive disaster prevention measures. Therefore, the scenario for calculating the required manpower and assuming a situation targets residents who need to be evacuated. Various variables used in the process and the causal relationship of each variable is shown in Fig. 1, as a diagram of how the radioactive disaster prevention measures work.

When the correlation between the necessary variables is connected in causal loop diagram, the structural characteristics of the resident protection measures can be identified from a macroscopic point of view.
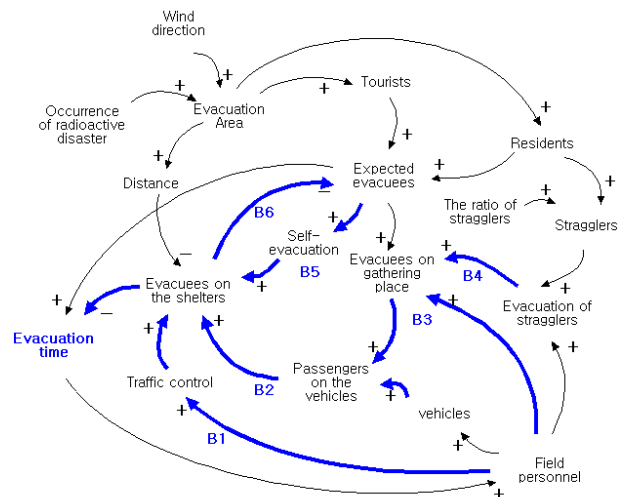

Fig. 1. High-level causal loop diagram

Six examples of correlation between the necessary variables as described above are shown below.

- B1 Loop (Field Personnel→Traffic control→Evacuees on the shelters→Evacuation time): The total evacuation time can be reduced by controlling the traffic and avoiding traffic congestions.
- B2 Loop (Field Personnel→Vehicles→Passengers on the vehicles→Evacuees on the shelters→Evacuation time): The total evacuation time can be reduced by running more vehicles for evacuation and move more residents at the same time.
- B3 Loop (Field Personnel→Evacuees on gathering place→Passengers on the vehicles→Evacuees on the

shelters→Evacuation time): The total evacuation time can be reduced if the residents gather the sooner.

・ B4 Loop (Field Personnel→Evacuation of stragglers→ Evacuees on gathering place→Passengers on the vehicles→Evacuees on the shelters→Evacuation time): The total evacuation time can be reduced if the stragglers are evacuated the sooner.

・ B5 Loop (Self-evacuation→Evacuees to the shelters →Evacuation time): The total evacuation time can be reduced if the more evacuees with own vehicle (self-evacuation).

・ B6 Loop (Evacuees to the shelters→Expected evacuees →Self-evacuation→Evacuees to the shelters→Evac-uation time): The evacuees on the shelters can be increased by the evacuees with own vehicles. it causes expected evacuees' reduction and then eventually leads evacuation time reduction as the B5 Loop presents.

The number of required support personnel to reduce the evacuation time can be calculated after the mathematical model is constructed. Because the high-level causal map is focused on minimizing the time to evacuate all residents, a new causal map links the low-level causal map to optimize the number of support personnel for practice.

2.2 Low-level causal loop diagram

To verify the accuracy of the modeling, another model was developed for the traffic countermeasures department. For this purpose, a low-level causal map was prepared based on the duties of the traffic countermeasure department, and the relationship between the variables is shown in Fig. 2, as a diagram of how the traffic countermeasure department works.
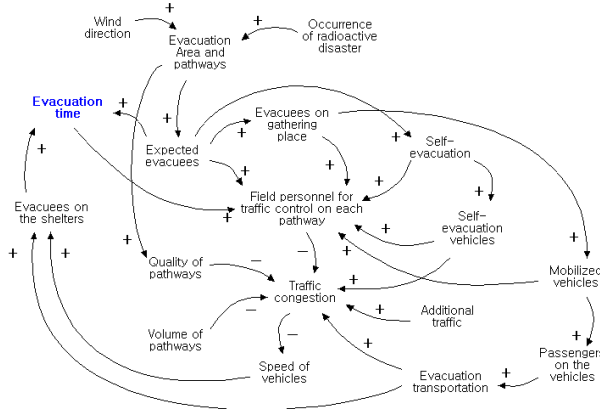

Fig. 2. Low-level causal loop diagram

For example, a higher number of evacuees with own vehicle instead of those mobilized by local governments will cause congestion on the evacuation route. When the vehicle speed decreases, the evacuation time increases, and support personnel will have to be deployed. When traffic congestion is resolved by increasing the number of support personnel, it can affect the speed of the vehicle and reduce the time eventually.

2.3 Estimation mechanism for optimal manpower

The evacuation time is a key stone on estimation mechanism for optimal manpower. By controlling the number of field personnel, it can define optimal number of field personnel, when evacuation times calculated on High-level and Low-level are equal.

For example, by monitoring ratio changes of evacuees with own vehicle as a predictor variable, when the times on High-level and Low-level are equal, the evacuation time is shown in Fig. 3, as graphs of evacuees to shelters that have calculated versus time and ratio of self-evacuation.
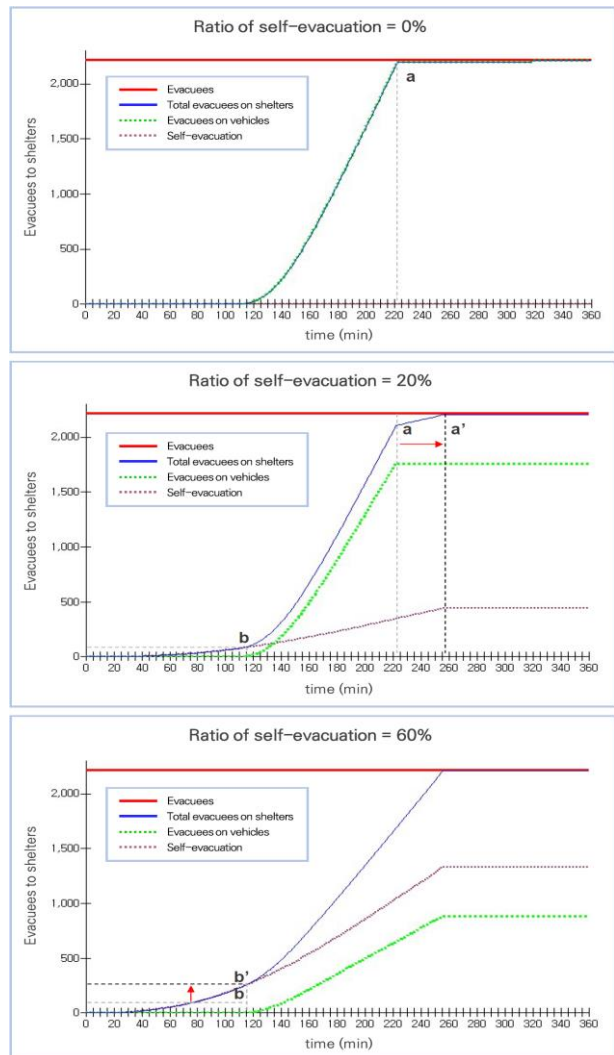

Fig. 3. Evacuees to shelters according to self-evacuation

If the evacuees with own vehicle are increased from 0% to 20%, total evacuation time is delayed by a'-a because of traffic congestion.

However, if evacuees with own vehicle are increased from 20% to 60%, evacuees to shelters are increased by b`-b early because people evacuate earlier.

As evacuees with own vehicle are increased from 0% to 60%, evacuation time, is equal on causal loop diagrams, is predicted to be delayed about 40 minutes from 222 minutes to 261 minutes. Thus, it also causes changes of the number of field personnel to solve the predicted traffic congestion.

To shorten total evacuation time, it makes the evacuation time calculated on Low-level be equal with the time on High-level by controlling the number of field personnel. When the times on diagrams are equal, it can define that the number of field personnel at the moment is reasonable. The result is shown in Fig. 4, as graphs of optimal field personnel on each traffic control points to optimize evacuation time.

Fig. 4. Estimation of field personnel on traffic control points

3. Conclusions

In this study, a model was developed for the purpose of calculating the required support personnel when an emergency occurs in local governments. Future research can assess the accuracy and reliability of the developed model by comparing and analyzing the predicted values provided by actual local governments.

It's completed to able to calculate evacuation time based on equalizing causal loop diagrams currently. Additionally, it will be developed to export the required

support personnel later and be completed by importing a low-level causal loop diagram for other emergency response departments by the same process.

The result of the simulation can be used by local governments to predict the required manpower for a radiological emergency. And it is expected to dedicate basic data for forming an emergency response organization. It can be utilized to minimize the waste of human resources in preparation for a radiological emergency and to effectively respond to the crisis.

REFERENCES

[1] Ministry of the Interior and Safety, "Guideline for Preparation Criteria of Field Action Manual", 2019
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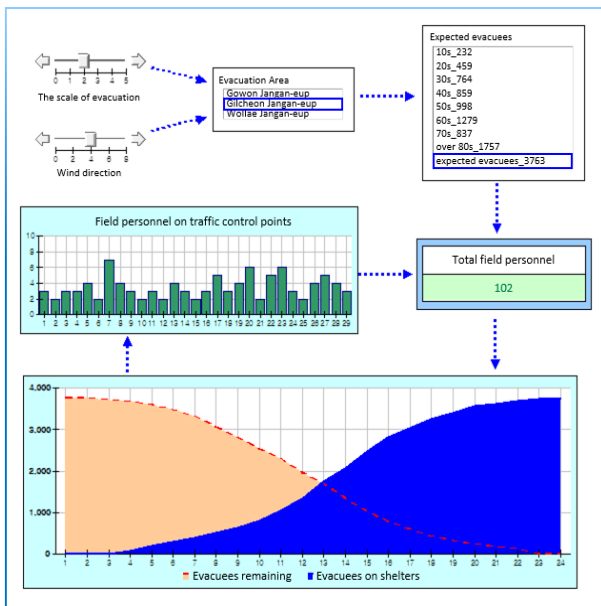[3] J. W. Forrester, "Principle of Systems", Wright-Allen Press, 1968.