Urban Space Design and Safety Evaluation from the Viewpoint of Evacuation Behavior of Users

by

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ABSTRUCT

To build safe city spaces and structures, it is very important to ensure the safety of the users in both normal and emergency situations as well as to secure structural strength. As a first step, we have developed a new evacuation model in which individual personality of the users, effect of disaster such as smoke and fire, and also the effects of evacuation guidance, can be considered. Using the model, safety of the spaces and efficiency of evacuation guidance are studied.

INTRODUCTION

Issues on structural behavior and/or physical strength of the structures have been main topic in construction of safe urban facilities. With the improvement of engineering technologies and construction materials, strength of the structures, especially in developed countries, has been getting better and better. (Of course, still, we have big problems on pre-code revision structures.) However, to build really safe urban spaces, it is very important to pay attention to the human evacuation behavior as well as structural problems[1), 2)]. Especially, when users aren't familiar with the space, its importance becomes much higher. Therefore, the space plan of urban facilities should be designed with proper consideration of users' evacuation safety and efficient evacuation guidance should be provided (**Fig. 1**). To discuss the human behavior, we developed a new computer simulation model in which human evacuation behavior of a lot of evacuees in huge sized facility or space can be easily simulated and situation in disaster and individual personal characteristics of every evacuee can also be considered[1)]. In this study, we propose a new philosophy of designing structures, in which urban spaces are designed from the viewpoint of safety of users considering their evacuation behavior. When we apply the proposed model to

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any existing space, the safety of the space can be evaluated from the viewpoint of human behavior, and also, optimum evacuation guidance can be discussed based on the computer simulation of human evacuation.

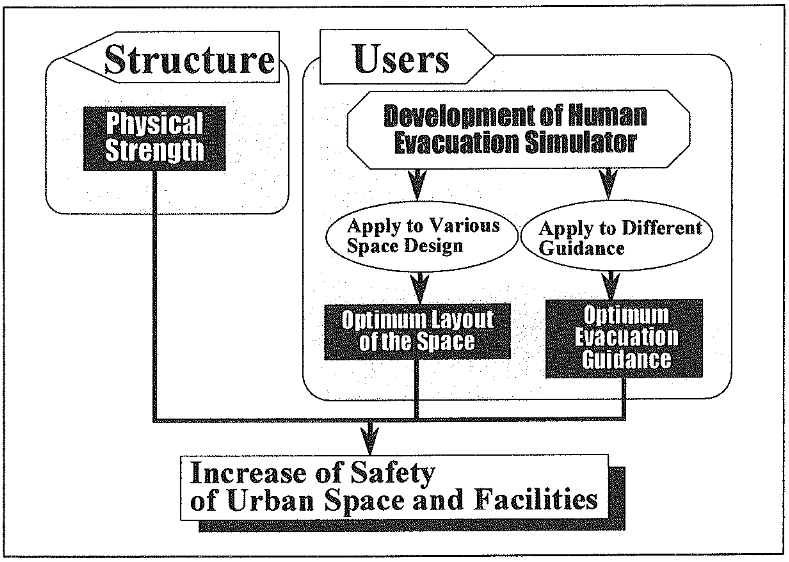

Fig. 1 Towards safer urban space and facilities

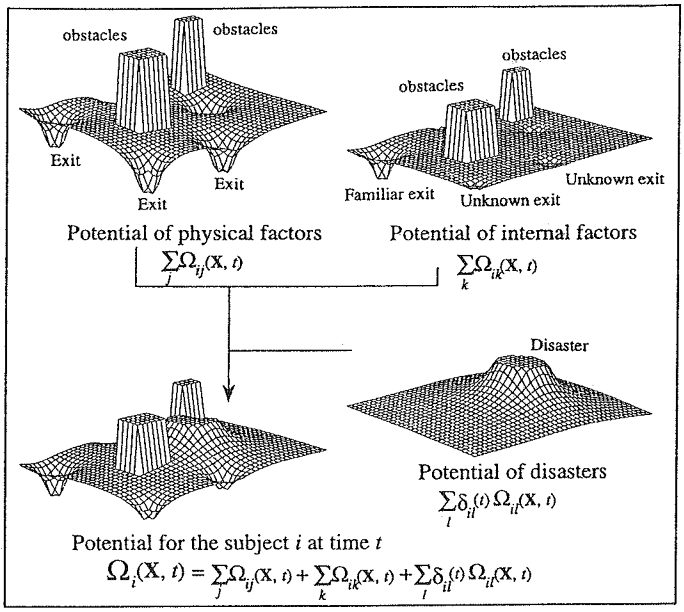

Fig. 2 Concept of potential model used in the simulation

METHOD

Figure 2 shows concept of a potential model used in the simulation. With the model, study space is divided into many grids and the characteristics of the space are modelled as a combination of three components of potentials. The first potential represents the effects of physical fac-

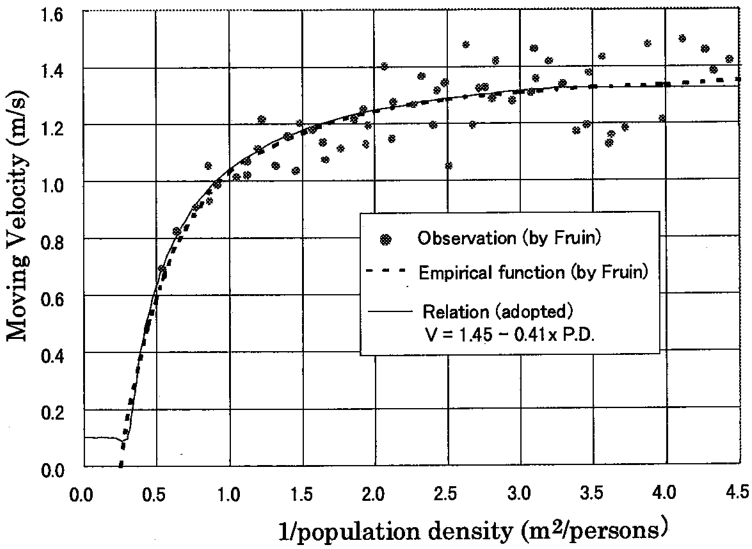

Fig. 3 Relation between moving velocity and population density (P.D.)[3]

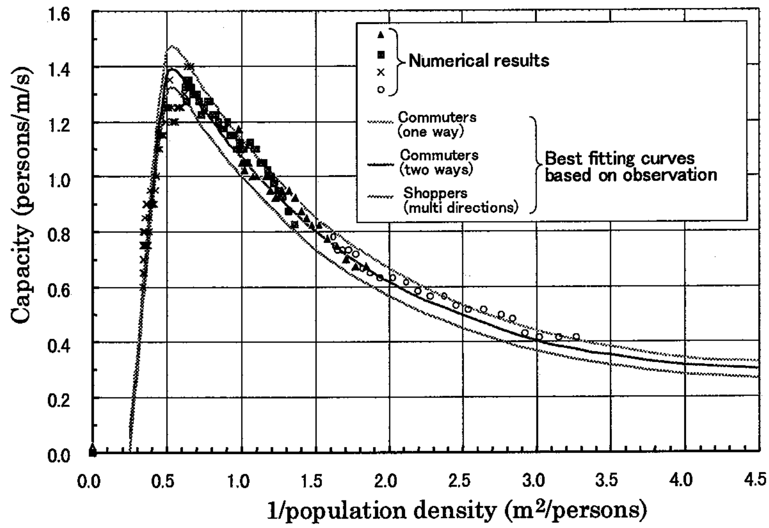

Fig. 4 Comparison between observation and numerical results

tors. The potential of wall or column is set to be high and that of exit is low. The second one shows the effects of difference among users. With this potential, individual personality and experience can be considered. The effects due to disaster are taken into consideration by the third potential. The total effects of a space can be obtained by combining these three potentials and the total potential is defined for each person with its location at each time step. By comparing the potentials of surrounding grids, a user selects the lowest grid for next direction. About a walking velocity, relation between walking velocity and population density obtained from observation shown in **Fig. 3**[3] is used. Reliability of the model is verified by comparing simulated results with observation. As shown in **Fig. 4**, numerical results obtained by the proposed model agree well with observations.

RESULTS

Using the model proposed here, human evacuation behavior in a large-scale exhibition hall in Tokyo with different booth arrangements is simulated. As an initial condition, 3,000 people are distributed inside the hall at random. **Figure 5** shows the relation between time and the number of people remaining inside the hall. Based on the results, it can be noted that there are big differences of safety for evacuation among these four layouts of the booth, all of which were used for exhibition before. **Figure 6** shows temporal and spatial distributions of persons inside the hall. Each dot represents a person trying to evacuate from an exhibition hall. The value of 'n' is the total number of people remaining inside the hall. From the result, we can discuss the

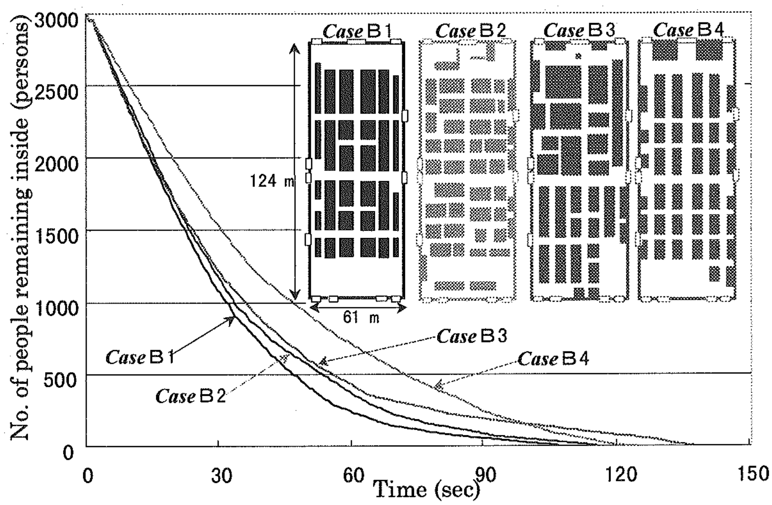

Fig. 5 Effects on evacuation due to different booth arrangements

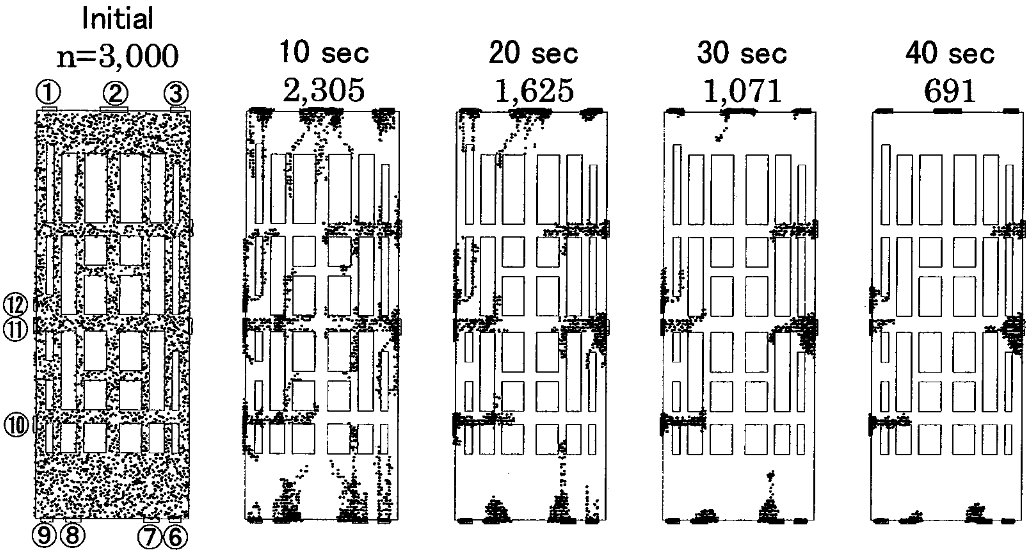

Fig. 6 Distribution of users remaining inside hall (Case B1)

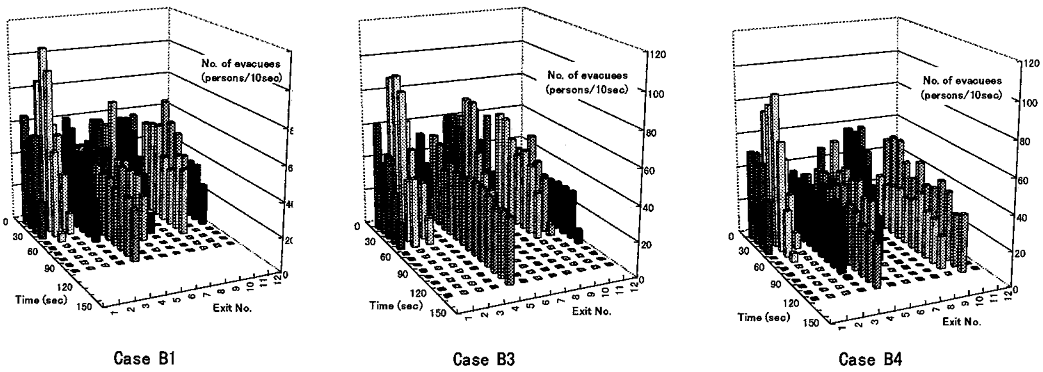

Fig. 7 Changes of the numbers of evacuees at each exit due to different booth arrangements

effects of booth arrangement and find proper plan from the viewpoint of evacuation safety of users. A role of each exit and/or pathway also can be discussed (**Fig.** 7)

Next, the effects of evacuation guidance are studied under a hypothetical condition that some of the exits are damaged due to some accident, e.g., by an earthquake. In **Figs. 8** and **9** (cases E2 to E4), black parts of some exits (2, 3 and 5) are damaged and cannot be used. From the results in these figures, it should be noted that proper guidance makes evacuation efficient, however, bad guidance without considering the disaster situation leads worse result.

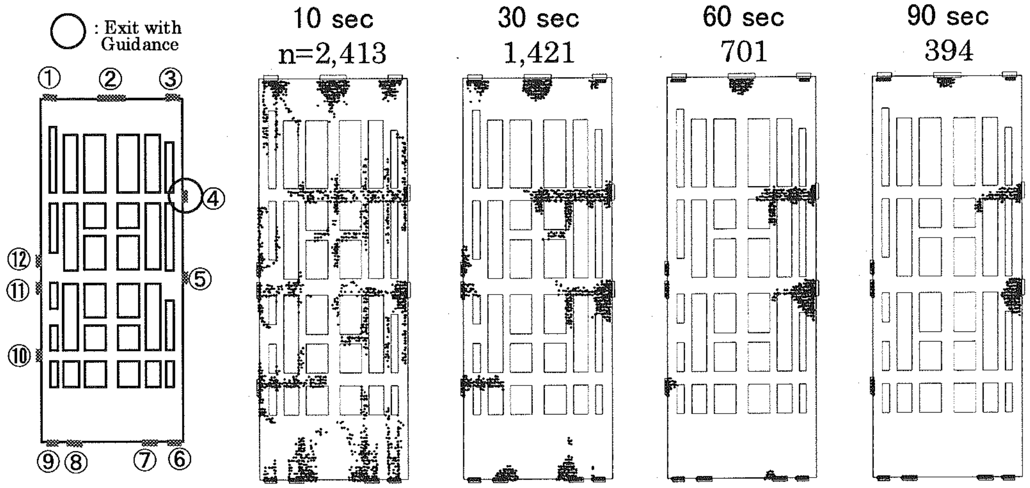

Fig. 8 Effects on evacuation efficiency of evacuation guidance

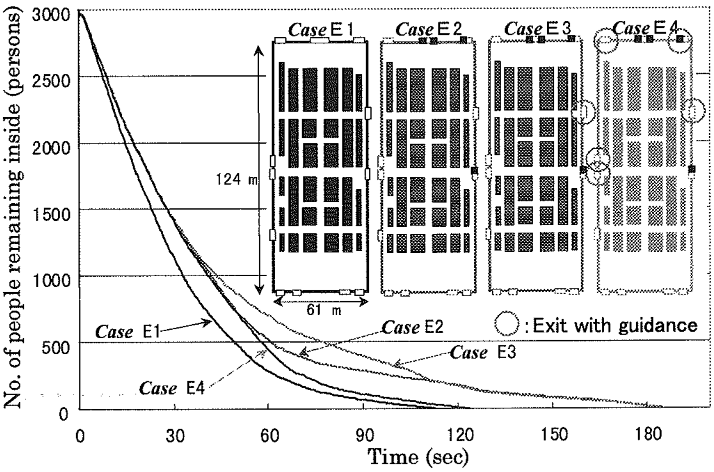

Fig. 9 Effects on evacuation due to different guidance

CONCLUSIONS

In this study, we have proposed a new philosophy for space design from users' evacuation viewpoint and introduced fundamental results for optimum real-time evacuation guidance system. Based on the results, human behavior in normal situation can be simulated well using the proposed model. However, it is very difficult to take into consideration of human response and

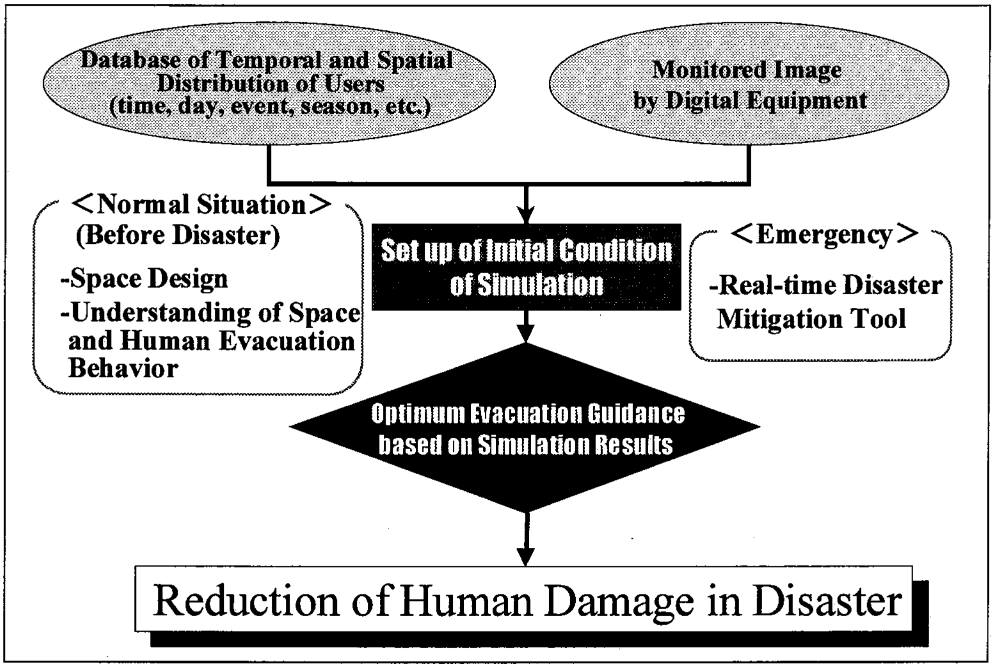

Fig. 10 Towards practical implementation

behavior in emergency. One of the main reasons is lack of data on human behavior in emergency, therefore, we have been monitoring human behavior at certain large-scaled (27,000 m^2) underground shopping facilities in Metropolitan area. As disaster situation and personal characteristics can be considered by the proposed model, when a good database on human behavior in emergency is prepared, modelling of emergency behavior can be done to some extent. Also, the algorithm of the model is very simple, CPU time required is very short. Using standard personal computer (CPU: DEC Alpha 300-600 MHz), simulation results introduced in the paper can be obtained in small fraction of actual time (0.1 % to several % of actual time). Therefore, in emergency, if we can carry out simulation using monitored real disaster situation, we can get proper evacuation guidance based on real situation within a short time that can be used in real-time evacuation guidance. This system can be regarded as an ideal model based on a concept of real-time disaster mitigation systems[4)]. To make it practical, still, we have a lot of issues, however, there are several useful ways to use the model for disaster mitigation as shown in **Fig. 10**. The method introduced can be applied to design safe urban space and structures in plan from users' evacuation viewpoint, and also, it can be used to understand space and human behavior and discuss an optimum evacuation guidance of existing structures in disaster.

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