1854

URBAN SPACE DESIGN AND SAFETY EVALUATION FROM THE VIEWPOINT OF EVACUATION BEHAVIOR OF USERS

Kimiro MEGURO[1] And Masaya HARADA[2]

SUMMARY

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, effects 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 topics 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 [Yokoyama et. al, 1995, Meguro, 1997]. 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 [Yokoyama et. al, 1995]. 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 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.

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.

[1] *International Center for Disaster-Mitigation Engineering, JapanE-mail: meguro@incede.iis.u-tokyo.ac.jp*

[2] *Engineer, Ms. Eng., Japan Highway Public Corporation, Tokyo, Japan*

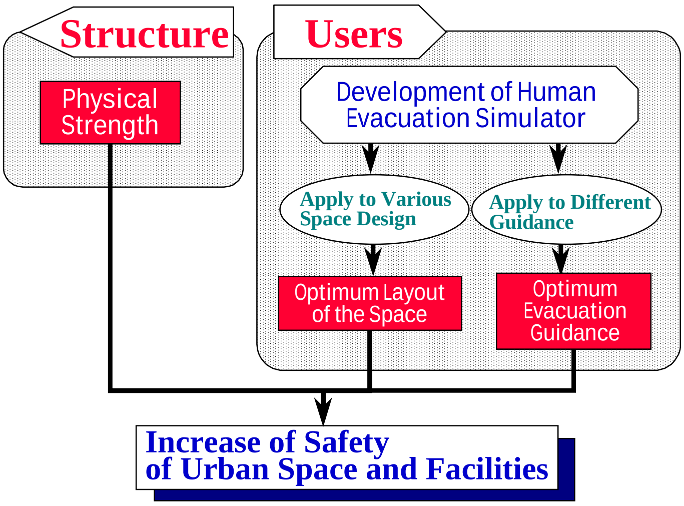


Fig. 1 Towards safer urban space and facilities

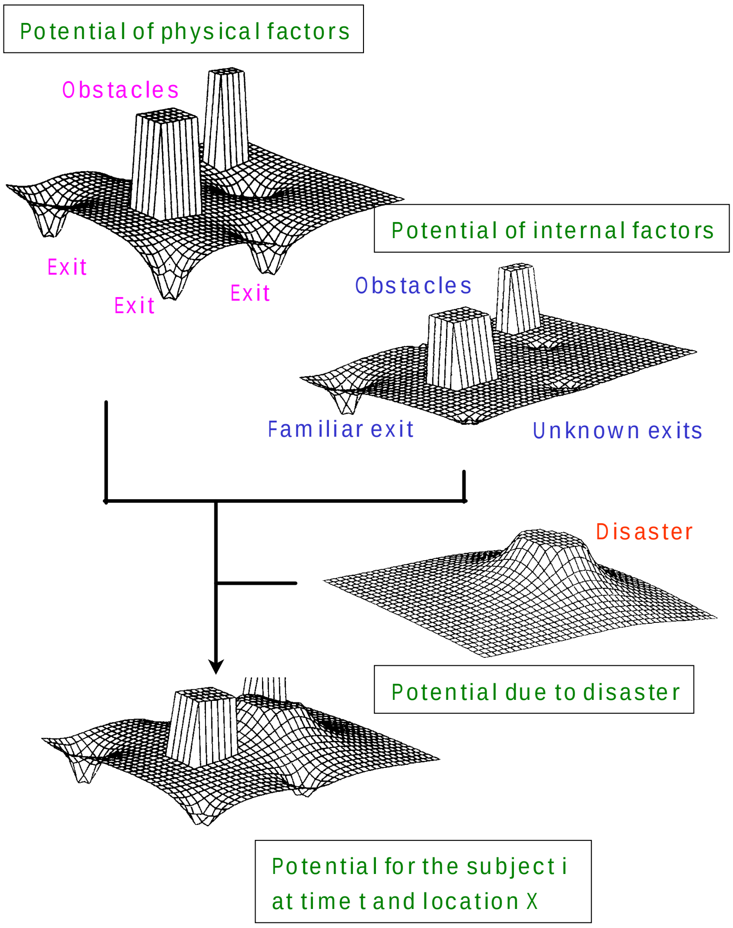


Fig. 2 Concept of potential model used in the simulation

The first potential represents the effects of physical factors. 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 a 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 [Fruin, 1974] 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.

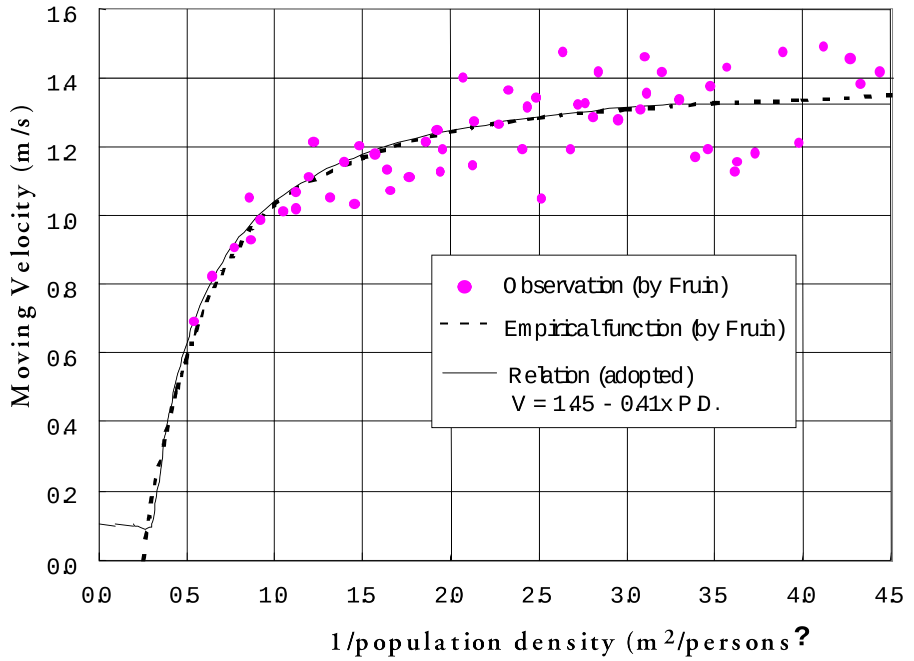


Fig. 3 Relation between moving velocity and population density (P.D.)[Fruin, 1974]

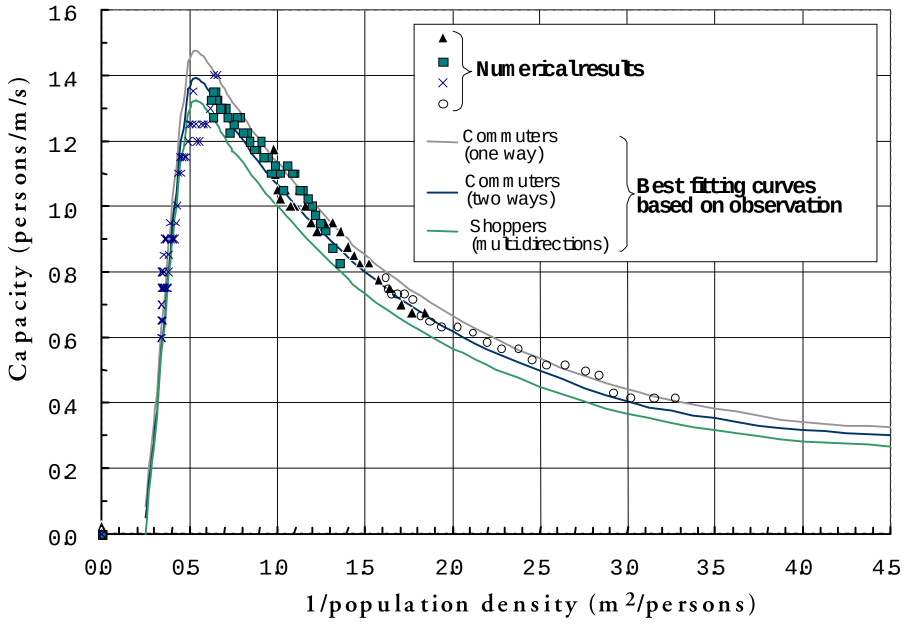


Fig. 4 Comparison between observation and numerical results

NUMERICAL ANALYSIS

Using the model proposed here, human evacuation behavior in a large-scale exhibition hall in Tokyo with different booth arrangements is simulated. All of the booth arrangements were actually used during past exhibitions. 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 effects of booth arrangement on users’ evacuation 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)

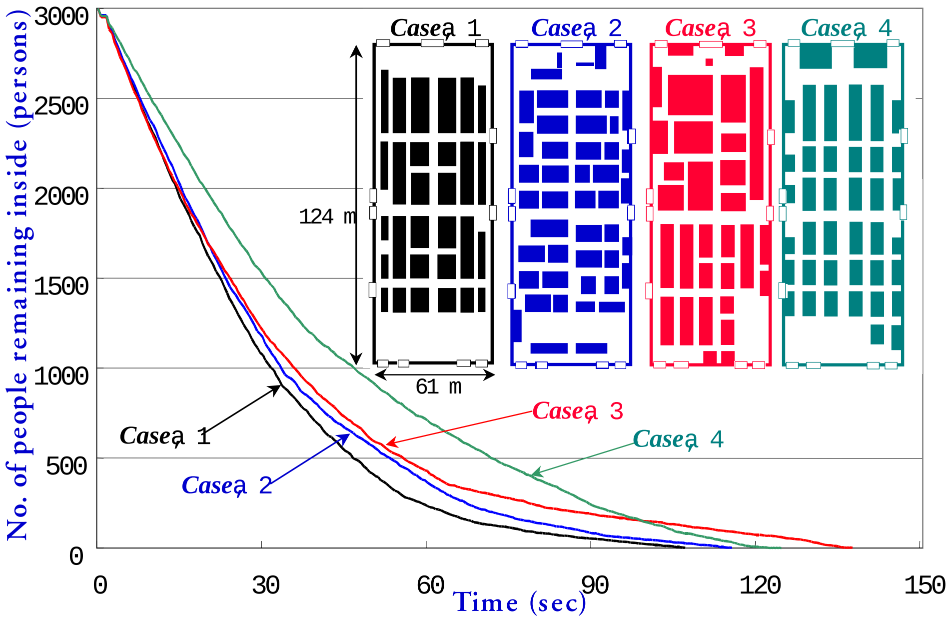


Fig. 5 Effects on evacuation due to different booth arrangements

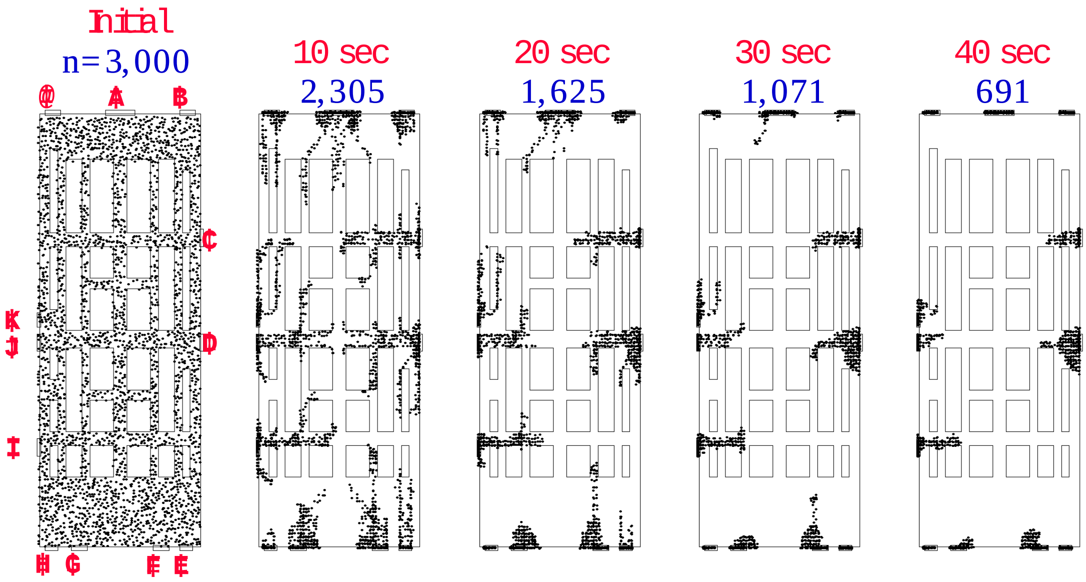
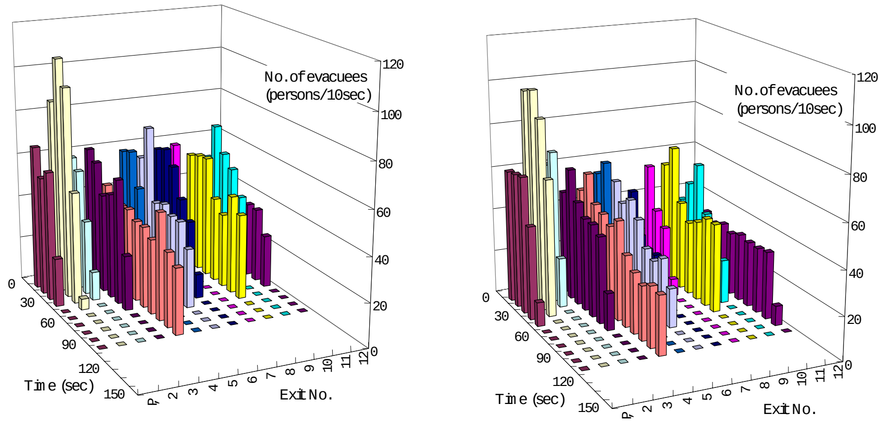
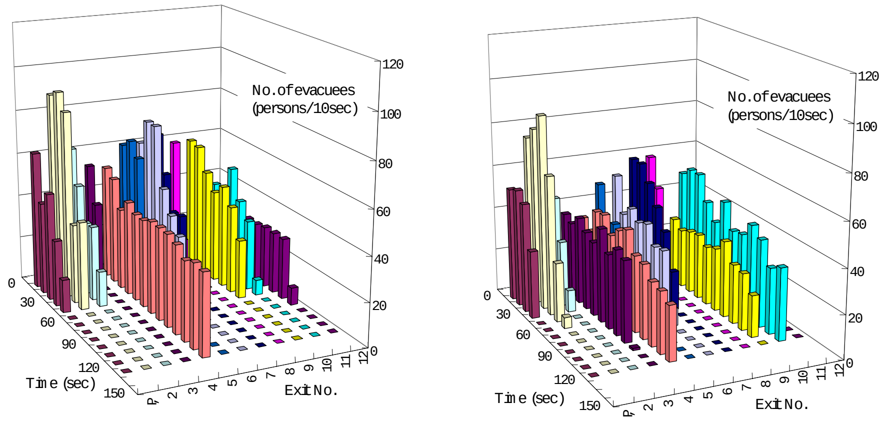


Fig. 6 Distribution of users remaining inside hall (Case B1)



Case B1 Case B2



Case B3 Case B4

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

Next, the effects of evacuation guidance are studied under a hypothetical condition that some of the exits are damaged due to some accident, such as 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. Case E1 is a normal case in which there is no damage. In Case E2, evacuation guidance is not considered while in Cases E3 and E4, evacuation guidance is taken into account. Because of the location of damaged exits, it seems that there will be many people around the upper right of the hall, therefore in Case E3, evacuation guidance is carried out at the exit 4. However in Case E3, too many people are leaded to the exit 4. The number of the people guided to the exit 4 is beyond the capacity of the exit. Therefore, evacuation efficiency became worse than that in case without guidance. Evacuation guidance in Case E4 is an optimum guidance based on the current situation (booth arrangement, distribution of damaged exits and people) which was obtained by various simulation case studies. We can see that evacuation efficiency is much better than previous two cases (E2 and E3) and it becomes similar to that in Case E1 having no damage. 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.

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 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-scale

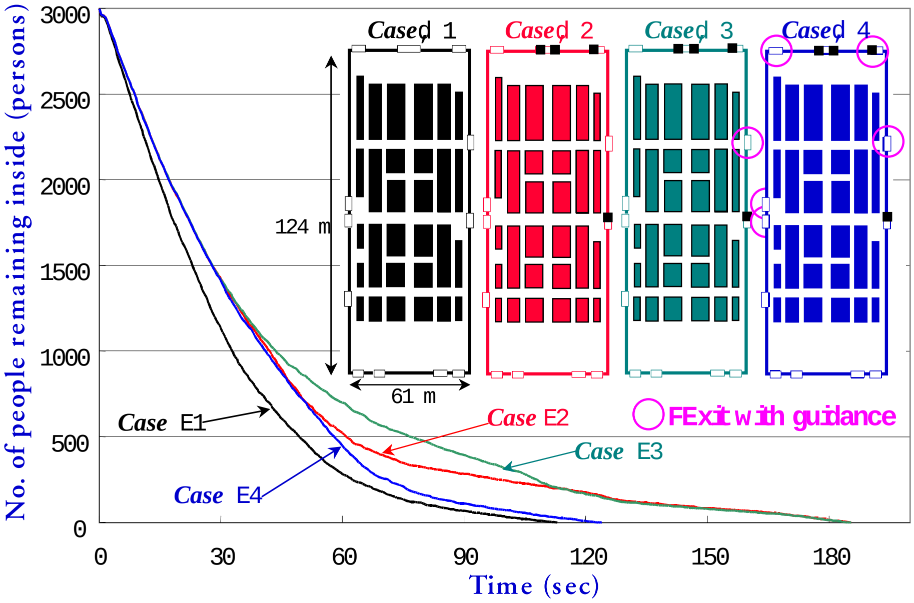


Fig. 8 Effects on evacuation efficiency of evacuation guidance

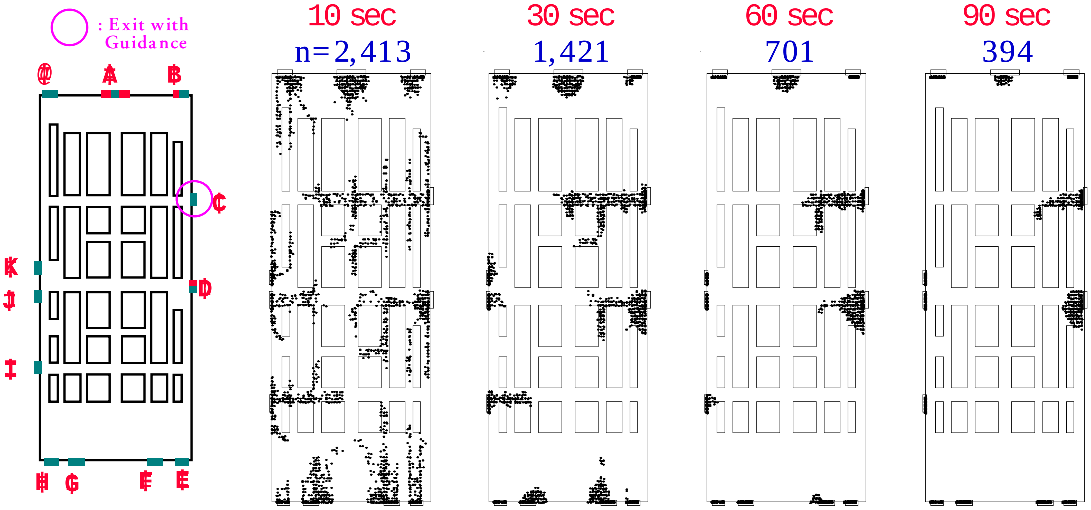


Fig. 9 Distribution of users remaining inside hall (Case E3)

(27,000 m^2) underground shopping facilities. As the proposed model can consider disaster situation and personal characteristics, 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 [Noda and Meguro, 1996]. 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.

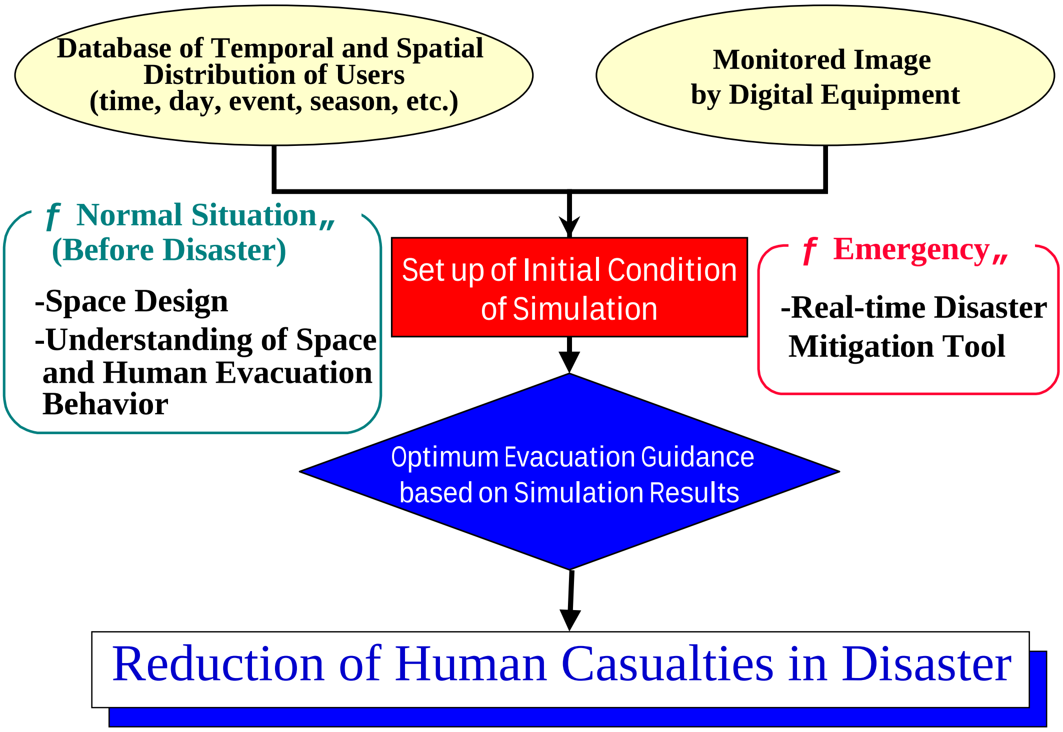


Fig. 10 Towards practical implementation

REFERENCES

1) Yokoyama, H, Meguro, K. Yamazaki, F. and Tsuneo K. (1995), “Computer simulation model for the analysis of evacuation in populous underground facilities”, *Proc. 9th Japan Earthquake Engineering Symposium*, pp. 2353-2358, 1995 (in Japanese).

2) K. Meguro, Y. Haga, F. Yamazaki and T. Katayama (1997), “Application of virtual reality to human evacuation behavior”, *Proc. 7th International Conference on Structural and Reliability*, 8 pages, 1997.

3) J. Fruin (M. Nagashima trans.) (1974) “Space for walkers”, *Kashima Publishing Institute*, 1974.

4) S. Noda and K. Meguro (1996), “A new horizon for sophisticated real-time earthquake engineering”, *Journal of Natural Disaster Science*, Vol. 17, No. 2, pp. 13-46.