

Successful Deriving Evacuation Factors of the Korean Aged

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Abstract

Objective: This study is a convergence research of social welfare, naval architecture, and ocean engineering for developing software of practical evacuation simulation for land/marine structures including social welfare facilities (elderly welfare facilities). **Methods:** In order to develop technologies of evacuation environment and object (evacuation subject) modeling, evacuation simulation, analysis/result visualization, etc. for life rescue in emergent situations such as fire, this study conducted an actual test at the Nam-gu Senior Welfare Center, and derived an evacuation test procedure and evaluation method from testing with elderly users, 15 persons. **Findings:** This study also developed Elderly Classification for Safe Evacuation (ECSE) usable in deriving factors for safe evacuation based on related literature. Crisis management is an extension of daily and structural risk management, and all structures designed and constructed should be evaluated technologically for the management. In this sense, such evaluation technologies should be developed first. The technology developed in this study is a system that enables prior testing of land and marine structures for the risk of disasters, and is usable at design and operation departments. Particularly in the operation of social welfare residential facilities for the social weak, one of the most important factors is life safety in emergency situations such as fire. All the licensed social welfare facilities are required to have guidelines for safety management and fire safety equipment according to relevant laws and regulations, but safety evaluation is still based on qualitative judgment, and there are few quantitative grounds for assessing the safety of target facilities. **Improvements/Applications:** Through these processes, evacuation simulation S/W satisfying the IMO Guideline was developed successfully for the first time in Korea. This study introduces the process of deriving safety factors before the development of virtual reality-based evacuation software.

Keywords: Elderly Classification for Safe Evacuation (ECSE), Elderly Welfare Facility, Evacuation Factors, Evacuation Simulation, Evacuation Software

1. Introduction

Having experienced disasters closely related to people's safe life such as the sinking of the Sewol Ferry in 2014 and the outbreak of MERS in 2015, and seeing various types of recent accidents and disasters including IS terrorist attacks in Europe, the Korean government takes the safety and protection of people from such risks as one of top-priority national tasks. In response to this direction,

the Ministry of Science and Technology is working on strategies to cope with national disasters.

With this social atmosphere, it is a natural phenomenon that social interest is increasing in safety management for elderly facilities, the number of which is rising rapidly along with the coming of an aged society, and it is keenly necessary to make systematic research on how to evaluate quantitatively the life safety of social welfare facilities¹.

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The safety of social welfare facilities have been covered sporadically in previous studies on space, but most of such studies were focused on convenience of living²⁻⁵ such as elders' behavior in using activity spaces, moving line analysis, and space utilization for the residents' smooth activities rather than on safety. Some studies dealt with more advanced safety management, risk management, evaluation plans, etc. for social welfare facilities⁶⁻⁸, but these studies are all limited to qualitative research.

Safety is the most important element in the operation of social welfare facilities, and safety assessment of facilities is a preventive measure to save human lives from critical situations such as fires and disasters⁹. Thus, this study performed primary simulation based on evacuation factors suggested by the International Maritime Organization (IMO) for evacuation analysis under the environment of marine structures, and then identified characteristics of evacuation dynamics through a test using actual evacuation scenarios. Through the evacuation test at an elderly welfare facility, we derived evacuation factors relevant to evacuation situations expected in actual buildings, and performed secondary simulation using the factors. In addition, the results of the simulation were analyzed in comparison with the results of the evacuation

test, and the significance of the differences was assessed. Through these works, this study established a procedure for deriving evacuation factors to perform more accurate computer simulation.

2. Evacuation Analysis Factors

2.1 The Concept of Evacuation and Evacuability

The safety of human lives is assessed with evacuability using evacuation simulation. As in equation (1), evacuability can be defined as a function of early conditions related to time such as environment, distribution, response time, and the behavioral characteristic (walking speed) of the Nth evacuation subject¹.

$$E = \text{function}\{\text{env}, d, r(t), \delta(ni); t\} \quad (1)$$

Figure 1 shows major factors influencing evacuation time include evacuation environment, the distribution of evacuees, evacuees' response time, and evacuees' walking ability, and elements to be considered for each factor in evacuation analysis are diagramed conceptually¹⁰.

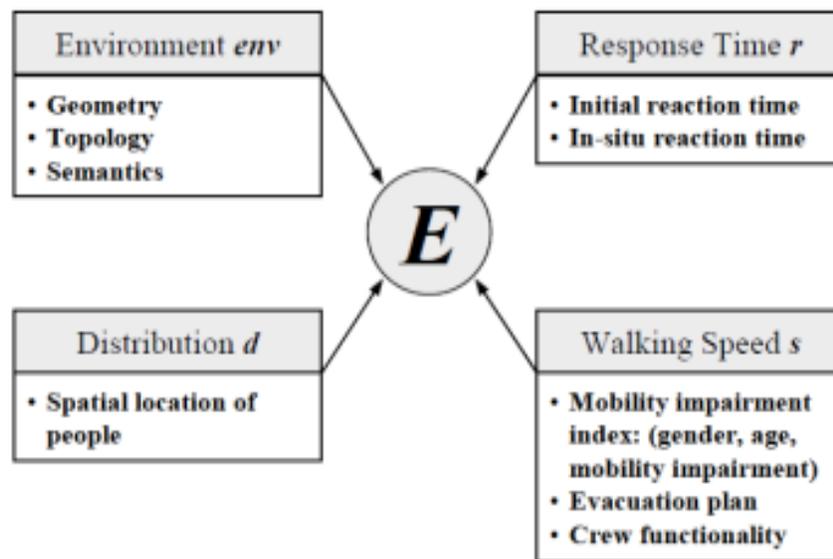


Figure 1. The concept of evacuability (E)

2.2 Evacuation Factors

2.2.1 Evacuation environment

Evacuation environment means the space where evacuation takes place. It indicates the route from the evacuees' initial location to the final destination and, at the same time, includes information about bottleneck, queuing, and change of speed that may happen during the evacuees' moving. In this study, evacuation environment indicates the elderly welfare facility where the test is performed. The same environment model was used in the simulations and the test.

2.2.2 Distribution of Evacuees

Evacuees begin evacuation from their initial location within the evacuation environment, and the location is determined by distribution according to the scenario. Moreover, an evacuee's location within a specific space is assigned at random.

2.2.3 Evacuees' Response Time

According to the IMO Guideline¹¹ on emergency evacuation simulation (Table 1), early response time shows uniform distribution, and its mean±standard deviation in seconds is 300±90 during the daytime, and 600±180 during the nighttime. In the test of this study, however, it was considered easy to respond because the evacuation environment was relatively narrow and the distance to the alarm telling the time of evacuation was relatively close. Accordingly, in consideration of the purpose of the evacuation test and such environmental differences, simulation was performed on the assumption that the early response time was 1~5 seconds. The distribution of response time in marine structures is as follows.

Table 1. Early response time during the daytime and nighttime (IMO Guideline)

Day/night	Minimum (sec.)	Average (sec.)	Maximum (sec.)
Day cases	210	300	390
Night cases	420	600	780

According to the definition by IMO, response time is the duration from the sounding of the alarm to the moment just before the evacuation act. This duration involves issues related to various acts until evacuation including recognizing stimuli, understanding them, and responding to them. Moreover, time taken by movements at the initial position before evacuation should be included in the response time.

In this test, response time of 1~5 seconds was applied as time taken for recognizing the evacuation situation, planning, and analyzing, and individuals' response time was taken into account separately because of differences from the environment of simulation. In scenario I, for example, the test participants in the physiotherapy room were all laid on the beds, but in the simulation environment, all the participants were standing and they began to move immediately after a given response time. In addition, situations such as putting on the shoes before evacuation may be considered in response time.

2.2.4 Evacuees' Walking Ability

In evacuation analysis, along with individuals' early response time, the walking speed of the subjects performing evacuation is very important for the accurate application of evacuees' behavioral characteristics. In this test, however, it was extremely difficult to define such characteristics of test participants due to insufficient data. Because the main purpose of this evacuation test was to derive accurate evacuation factors by identifying these characteristics, we performed the primary simulation using existing criteria in making initial scenarios. At present, there are criteria for marine structures provided by IMO, and these criteria were used in order to examine evacuation dynamics such as bottlenecks in each scenario. Table 2 shows walking ability according to age suggested in the IMO Guideline for men and women at the age of 65 and 75. The ability was presented in the speeds of walking on a flat ground, ascending stairs, and descending stairs and standard deviation was given for each value to show deviation of walking ability among the evacuees.

Table 2. Walking ability according to age and gender (IMO Guideline)

Group	Flat (m/s)	Stair-up (m/s)	Stair-down (m/s)	Standard Deviation
65-year-old women	0.75	0.49	0.60	0.25
75-year-old women	0.67	0.43	0.54	0.25
65-year-old men	1.05	0.52	0.66	0.25
75-year-old men	0.97	0.46	0.60	0.25

2.3 Evacuation Test

This test was performed at an elderly welfare center in Nam-gu, Busan in February, 2014. The center is operating various hobby, leisure, and education programs as well as social participation programs such as volunteer services and employment programs. About 20 employees

are working at the center situated in a building with four stories above and one under the ground (Figure 2).

For the test, 15 elders with representativeness were sampled for the groups. They were asked to walk a 5m long hallway and to ascend and descend a certain length of stairs at a speed similar to that in an evacuation situation,



Figure 2. Test place.

Table 3. Questionnaire survey items related to MII

Type	Item	Weight
1	I walk often.	1
1	I walk occasionally.	0
1	I don't walk often.	-1
2	I walk fast.	1
2	I walk an average speed.	0
2	I walk slowly.	-1
3	I have a knee disease.	-2
3	I had a knee disease, but am all right now.	-1
3	I don't have any knee disease.	0
4	I respond quickly to an unexpected situation.	1
4	I respond to an unexpected situation at an average speed.	0
4	I respond slowly to an unexpected situation.	-1

and the walking speed was measured. From the measurements were derived new values using the correlation ratio with the speeds of walking on a flat ground, ascending stairs, and descending stairs in the IMO Guideline with 4 scenarios which were made for fire situation? With the derived walking ability factors, secondary simulation was performed. Additionally, the accuracy of the walking ability factors was refined in consideration of the 15 test participants' age and the results of a preliminary survey. Table 3 shows constants for calibrating walking ability in the preliminary questionnaire survey conducted in order to get evacuees' Mobility Impairment Index (MII). Weight was applied through the evaluation of the questionnaire items, and walking speed was increased/decreased by 2% per point of the overall mean score.

3. Development of ECSE

This test assigned a weight to each of the questionnaire survey items for MII as in Table 3. For more accurate assessment of the evacuation factors, however, elders' characteristics should be considered precisely. Thus, this study developed Elderly Classification for Safe Evacuation (ECSE) usable in deriving factors for safe evacuation based on related literature. Figure 3 shows 4 factors for safe evacuation. There are physical factors, sensory factors, intellectual factors and emotional factors which have to be considered for safe evacuation of elderly. Although this test did not apply individual weights based on ECSE, we expect the use of ECSE in future studies for more precise tests.

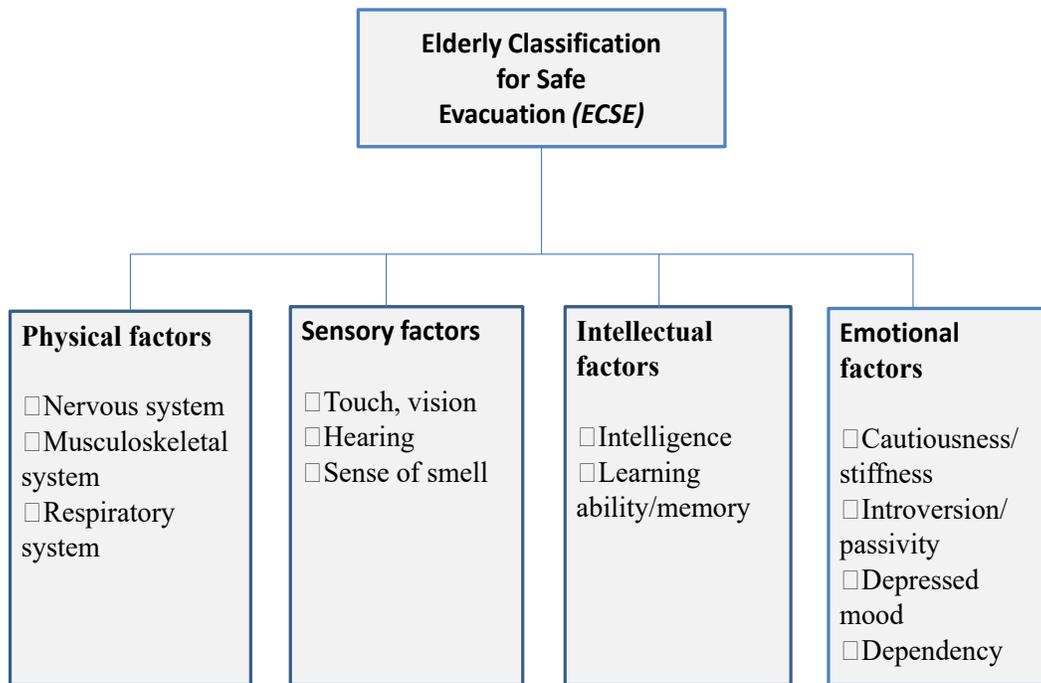


Figure 3. ECSE for safe evacuation

4. Results

Evacuation routes used by the evacuation agents during the two simulations and one test were recorded according to time, and the analyzer replayed the results for

evacuation performance analysis. Moreover, it was mentioned that further research would be possible not only to analyze evacuation time but also to find the optimal evacuation routes through probabilistic evaluation of evacuation conditions and results.

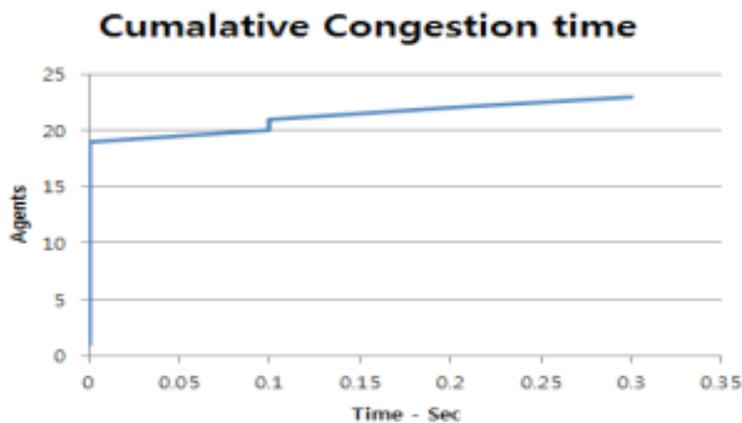


Figure 4. Congestion time by agent.

As Figure 4, analysis of congestion time in the total evacuation time in each agent will be useful to find or define the optimal routes. In general, the agent who escaped first will have the shortest congestion time.

5. Discussion

“A developed country in economy but an underdeveloped country in safety,” this may be the most correct evaluation of Korea for its crisis management and responsiveness. In terms of the safety management level of the society, Korea is still an underdeveloped country and the country should improve its systems for coping with disasters and preventing accidents. Furthermore, current systems need to be inspected thoroughly. Crisis management is an extension of daily and structural risk management, and all structures designed and constructed should be evaluated technologically for the management. In this sense, such evaluation technologies should be developed first. The technology developed in this study is a system that enables prior testing of land and marine structures for the risk of disasters, and is usable at design and operation departments.

Particularly in the operation of social welfare residential facilities for the social weak, one of the most important factors is life safety in emergency situations such as fire. All the licensed social welfare facilities are required to have guidelines for safety management and fire safety equipment according to relevant laws and regulations, but safety evaluation is still based on qualitative judgment, and there are few quantitative grounds for assessing the safety of target facilities.

This study conducted joint research of social welfare and naval architecture, focusing on the common interest of safe evacuation. Its purpose was to develop software for evaluating life safety and applying it through direct experiment upon quantitative evaluation methods and factors in emergency situations such as fire at elderly welfare facilities.

This study derived factors related to safe evacuation in elderly welfare facilities and developed ECSE, and the results have three implications as follows.

First, the procedure developed in this study for deriving evacuation factors improved the accuracy of simulation results. Thus, through additional tests, it is

believed possible to develop and utilize a simulation procedure for more accurate evacuation factors.

Second, ECSE developed through this study, although not applying a weight to individual agents, is usable for precise tests in the future.

Third, the simulation technique obtained through this study is expected to be used in flow planning and evacuation guideline development in similar welfare facilities and ultimately to contribute to the safety of elderly welfare facilities and, moreover, social welfare facilities for social minorities.

This study is meaningful as interdisciplinary research of social welfare and naval architecture, which can be extended to software development and production by a software company. That is, if the development of evacuation simulation software technology for social welfare facilities is completed through interdisciplinary and industrial-academic joint research, evacuation simulation can be performed for emergency situations such as fire not only at social welfare facilities but also at land and marine structures. Based on the results of the simulation, moreover, the locations of facilities and safety personnel can be adjusted, and structures can be designed and operated in a way of minimizing the loss of lives and properties. For these purposes, this study introduced the safety factor derivation process before the development of software.

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