AHP 분석을 통한 노인요양병원의 화재안전성 평가지표 개발

신수경 · 배영훈* · 최준호**†

부경대학교 건축 · 소방공학부 대학원생, *그레니치대학교 박사후연구원, **부경대학교 건축 · 소방공학부 교수

Development of Fire Safety Evaluation Indices for Long-term Care Hospitals for the Elderly through Analytic Hierarchy Process Analysis

Soo-Kyung Shin · Young-Hoon Bae* · Jun-Ho Choi**†

Graduate Student, Division of Architectural and Fire Protection Engineering, Pukyong National University,

*Post-Doctoral Research Fellow, Fire Safety Engineering Group, University of Greenwich,

**Professor, Division of Architectural and Fire Protection Engineering, Pukyong National University

(Received October 8, 2021; Revised October 18, 2021; Accepted October 18, 2021)

ABSTRACT

Long-term care hospitals for the elderly are places for the elderly and patients with impaired mobility to live in, but these places face a high risk of great damage in the event of a fire. The standards for fire safety at long-term care hospitals for the elderly are limited to inspection of firefighting facilities and training plans, with no index to evaluate the evacuation plans, facilities for evacuation in case of fire, and the fire response manuals of long-term care hospitals for the elderly. Therefore, this study tries to carry out a basic analysis and establish fire safety evaluation indices for long-term care hospitals for the elderly. To that end, the study derives the importance and priorities of the indices related to fire safety in long-term care hospitals for the elderly through an analytic hierarchy process questionnaire surveying 44 firefighting experts. Finally, considering the importance and priorities of the indices, this study presents fire safety evaluation standards (drafts) for long-term care hospitals for the elderly.

Keywords : Long-term care hospital for the elderly, Analytic hierarchy process (AHP), Fire safety evaluation standard

1. Introduction

1.1 Background and purpose of study

The number of long-term care hospitals for the elderly is increasing along with the growing number of the elderly population in South Korea⁽¹⁾. Long-term care hospitals for the elderly are spaces where the elderly and patients with impaired mobility can live, but such places face a high risk of great damage in the event of a fire, as revealed in several recent accident cases. The fire that engulfed the Miryang Sejong Hospital in January 2018 led to the largest number of casualties (death: 47; injuries: 143) caused by fire in long-term care hospitals for

the elderly in South Korea. This large number of casualties can be attributed to problems⁽²⁾ such as inadequate management of fire preventive blocks like fire doors and vertical penetrations, large number of patients unable to evacuate by themselves, delayed reporting to 119, and insufficient personnel to manage critically ill patients. This trend has been observed even more recently, for example, when fire struck Gimpo Nursing Hospital in 2019 (death: 2; injured: 47) and Yoonho Hospital in Goheung in 2020 (dead: 3; injured: 27).

Current institutional measures to ensure fire safety in long-term care hospitals for the elderly include consent for firefighting at the time of issuing building permits, self-inspection

of firefighting facilities, and a mandatory certification system for nursing hospitals. However, existing systems focus only on fire extinguishing equipment and training plan inspections; that is, there is no evaluation standard for evacuation plans, the number of persons assisting in evacuation, evacuation and fire-prevention facilities, responses to fire, firefighting activities, preparation of fire safety manuals, firefighting education, and firefighting training specific to long-term care hospitals for the elderly.

To solve the above problems, this study tries to establish fire safety evaluation standards and present fire safety evaluation indices for long-term care hospitals for the elderly. The study focuses on the importance and priorities of the fire safety evaluation items for long-term care hospitals for the elderly.

1.2 Scope and Method of Study

This study analyzes the importance and priorities of the fire safety evaluation items and presents fire safety evaluation standards (draft) for long-term care hospitals for the elderly. For this, the study first derives the structure of the analytic hierarchy process (AHP) survey from previous studies related to fire safety in long-term care hospitals for the elderly⁽²⁻¹⁴⁾, literature reviews⁽¹⁵⁾, and a review of special fire investigation items (Table 1). An AHP survey then questions 44 experts on firefighting (professors of firefighting-/architecture-related departments, firefighting officials, and firefighting engineers, managers, and architects) to assess the importance and priorities of the fire safety evaluation items for long-term care hospitals for the elderly. Finally, based on the AHP questionnaire survey results, the study presents fire safety evaluation indices for long-term care hospitals for the elderly.

2. Review of Fire Safety Evaluation Standards and Problems of Long-term Care Hospitals for the Elderly

Currently, the fire safety inspection and evaluation standards for long-term care hospitals for the elderly include self-inspection of firefighting facilities as well as a mandatory certification system for nursing hospitals. The self-inspection is carried out through either an inspection of operational functions (by artificially manipulating firefighting facilities, etc.) or a comprehensive precise inspection (including the inspection of operational functions and checking whether the structural standards for the components of firefighting facilities, etc., conform to fire safety standards and building laws). This depends on the scale of firefighting facilities^(16,17). Nursing hospitals that are required to install a sprinkler system have to undergo a comprehensive precise inspection once a year, but those with a total floor area

Table 1. Reference of the Hierarchical Structure

Level 1	Level 2	Reasons for deriving	Reference
A	A.1	P, SR ⁽¹⁵⁾	(3)(9)(13)(15)
	A.2	P, SR ⁽¹⁵⁾	(7)(8)(15)
	A.3	P, SR ⁽¹⁵⁾	(3)(15)
	A.4	P, SR ⁽¹⁵⁾	(3)(12)
B	B.1	P	(2)(3)(4)
	B.2	I	
	B.3	P	(3)(5)
	B.4	P	(2)(3)(9)(14)
C	C.1	I	
	C.2	I	
	C.3	I	
	C.4	I	
D	D.1	P	(3)(9)(10)(11)
	D.2	P, SR ⁽¹⁵⁾	(9)(10)(12)(13)(14)
	D.3	P	(3)(10)(12)

P: Previous research; SR: Standard review

I: Investigation list of firefighting

of 300 to 600 m², which are required to install a simple sprinkler system, need to undergo only an inspection of their firefighting facilities' operational functions. Even if a long-term care hospital for the elderly has to undergo a comprehensive precise inspection because it has a sprinkler system, the inspection of firefighting facilities, and so on⁽¹⁸⁾, as listed in Appendix 3 of the notification regarding firefighting facility self-inspection items, would require only simple matters related to evacuation and fire-prevention facilities, with checklists for firefighting facilities; that is, fire extinguishing facilities, alarm facilities, evacuation facilities, fire extinguishing water facilities, and other matters. The current self-inspection of firefighting facilities checks and evaluates only the firefighting facilities, and not the fire safety measures, of long-term care hospitals for the elderly.

In addition, the standards for examination and certification of the "compulsory certification system for nursing hospitals" (as required by the Ministry of Health and Welfare and Korea Institute for Healthcare Accreditation, who give certification marks valid for four years) implemented for existing and new nursing hospitals since January 2013 by the Ministry of Health and Welfare require checks for matters related to fire safety. According to "Phase 3 Nursing Hospital Certification Examination Standard Guidelines" published in September 2020 and effective from 2021, the results of examining fire safety management activity items (fire prevention and inspection plan, firefighting training and safety education, whether staff members are well-acquainted with the response system, and familiarity with

certification investigation) should be classified as high, medium, or low level during the certification process, but there is no objective standard, with the examination remaining only at the level of manual and training plan inspection⁽¹⁹⁾.

To summarize, the current evaluation of the fire safety of long-term care hospitals for the elderly consists only of the inspection of firefighting facilities or manuals and training plans based on the examiner's subjective judgment. In other words, there is no evaluation index to evaluate the refuge plan, critically ill patient evacuation plan, inadequate number of evacuation assisting personnel, and availability of evacuation/fire-prevention facilities. This issue has been pointed out as a major problem of fire safety in long-term care hospitals for the elderly.

3. Design of AHP Survey for Establishment of Fire Safety Evaluation Standards

3.1 Design of AHP Questionnaire Survey

AHP analysis follows a problem-solving model. It constructs a hierarchical structure based on major and detailed factors of problems and calculates the importance of each item through pairwise comparison depending on the evaluator's knowledge, experience, intuition, subjective judgment, and mathematical processing techniques⁽²⁰⁻²²⁾. AHP analysis generally adopts the following procedure in five steps: Step 1: hierarchical structure design; Step 2: pairwise comparison between individual elements through surveys; Step 3: calculation of relative importance; Step 4: consistency check; and Step 5: determination of relative weights of individual elements.

For AHP analysis, the hierarchical structure of the problem to be solved should first be designed (Step 1). To this end, this study derives the elements related to fire safety evaluation standards for long-term care hospitals for the elderly by examining the data of previous studies and the literature, and reviewing the special fire investigation items for designing the

AHP hierarchical structure and enhancing the completion of the hierarchical structure.

Finally, the AHP hierarchy is divided into 4 upper layer items and 15 lower layer items (see Table 2 and Figure 1). The four upper layer items are "refuge and fire prevention

Table 2. Participant Information

Type		Number of participant (%)		
		P	E	F
Total		9	19	16
Education	Bachelor	-	6 (32%)	11 (69%)
	Master	-	9 (47%)	-
	Doctor	9 (100%)	3 (16%)	-
	Etc.		1 (5%)	5 (31%)
Career	1~4 year		2 (11%)	
	5~9 year	4 (44%)	1 (5%)	2 (13%)
	10~14 year	1 (11%)	7 (37%)	6 (38%)
	15~20 year	1 (11%)	2 (11%)	3 (19%)
	More than 20 years	3 (33%)	7 (37%)	5 (31%)
Major	Architectural	4 (44%)	8 (42%)	
	Mechanical & Electricity	3 (33%)	2 (11%)	
	Fire protection & Chemical	2 (22%)	7 (37%)	5 (31%)
	Etc.		2 (11%)	11 (69%)

P: Professor (Department of fire protection and department of architectural, E: Firefighting professional engineers, F: Firefighters

Figure 1. AHP hierarchical structure.

plans for evacuation” (A), “results of inspection of firefighting facility operation” (B), “possibility of fire-extinguishing activities of the fire brigade” (C), and “fire safety management and prevention” (D). The lower layer of the refuge and fire prevention plans for evacuation (A) consists of four items: “critically ill patients’ evacuation support plan” (A.1), “designation of evacuation areas in each floor and utilization plan” (A.2), and “adequacy of establishment of the refuge path plan” (A.3). The lower layer of “results of inspection of firefighting facility operation” (B) consists of four items: “results of inspection of the operation of the automatic fire detection system” (B.1), “results of inspection of the operation of indoor fire hydrants” (B.2), “results of inspection of the operation of the automatic fire extinguishing equipment (sprinkler, etc.)” (B.3), and “evacuation instrument inspection and utilization plan” (B.4). The lower layer of the “possibility of fire-extinguishing activities of the fire brigade” (C) consists of four sub-items: “securing a firefighting mobilization route” (C.1), “fire engine mobilization time” (C.2), “fire brigade activity space around the building” (C.3), and “possibility of expansion of combustion to adjacent buildings” (C.4). Finally, the lower layer of “fire safety management and prevention” (D) consists of three sub-items: “writing of and education on a customized fire response manual” (D.1), “regular fire suppression and evacuation drills” (D.2), and “inspection of facilities on firefighting, construction, electricity, etc.” (D.3).

Individual elements are compared pairwise through expert surveys (Step 2). The survey results are then analyzed through the following steps (Steps 3-5).

First, a pairwise comparison matrix A (preference of item j over item i) based on the questionnaire survey is obtained, and W (column vector), the relative importance of matrix A , is calculated through $\lambda_{\max}$, the largest value among the characteristic equations (Step 3). The consistency ratio is calculated through consistency verification using $\lambda_{\max}$. Values whose consistency ratios exceed 0.2 are not analyzed (Step 4). Finally, the relative weights of individual elements are determined (Step 5).

3.2 Survey Method and Current Status of Respondents

The survey uses methods such as e-mail, SNS, and in-person questionnaires. All respondents participating in the survey were provided detailed explanations about the purpose of the survey, with an outline of the AHP and the derived AHP hierarchy and items. Following the questionnaire survey, 49 sheets were collected, from which 44 were considered for data analysis, excluding 5 whose consistency ratios exceeded 0.2.

The survey respondents’ personal information is provided in Table 2. By occupational group, 9 professors of firefighting-/

Table 3. Result of AHP Survey

Level 1		Level 2		Global weight	Global priority
Type	Weight	Type	Weight		
A	0.423	A.1	0.259	0.109	3
		A.2	0.214	0.090	7
		A.3	0.280	0.118	2
		A.4	0.248	0.105	5
B	0.121	B.1	0.408	0.049	8
		B.2	0.099	0.012	14
		B.3	0.367	0.044	9
		B.4	0.127	0.015	13
C	0.107	C.1	0.388	0.042	10
		C.2	0.364	0.039	11
		C.3	0.160	0.017	12
		C.4	0.088	0.009	15
D	0.349	D.1	0.262	0.091	6
		D.2	0.433	0.151	1
		D.3	0.306	0.107	4

architecture-related departments, 16 firefighters, and 19 firefighting engineers/managers and architects participated in the survey. Most of the survey respondents were experts in various fields with work experience of not less than 10 years.

4. Analysis of Importance of Fire Safety Evaluation Items and Presentation of Evaluation Standards (Draft)

The results obtained from analyzing the importance and priorities of fire safety evaluation items for long-term care hospitals for the elderly are shown in Table 3.

First, the item with highest importance in the upper layer was “refuge and fire prevention plans for evacuation” (A) with a ratio of 0.423, followed by “fire safety management and prevention” (D) with at a ratio of 0.349, “firefighting facility operation inspection results” (B) with a ratio of 0.121, and “possibility of fire-extinguishing activities of the fire brigade” (C) with a ratio of 0.107 (Figure 2). The importance ratio of two elements selected as the most important, refuge and fire prevention plans for evacuation (A) and fire safety management and prevention (D), was found to be 77% of the total. Thus, the survey showed that the respondents considered preventive activities the most important element in securing the safety of long-term care hospitals for the elderly. This means that because of the characteristics of long-term care hospitals for the elderly, where many patients find evacuation by themselves

Figure 2. Weight in AHP survey (level 1).

difficult (due to impaired mobility), the respondents considered it more important to prevent the occurrence of fire through preventive steps such as proper management of refuge and fire preventive blocks, fire safety activities, and education and training, to carry out checks at normal times, and to minimize the damage in case of fire through countermeasures such as using refuge and fire preventive blocks and reducing the casualties of patients with impaired mobility.

Next, an analysis of importance of individual items in the lower layer relating to refuge and fire prevention plans for evacuation (A) showed the importance of the adequacy of the establishment of the refuge path plan (A.3) to be highest at 0.280, and the importance of the designation of evacuation areas in each floor and utilization plan (A.2) to be lowest at 0.214. In other words, the analysis found the items in the lower layer of the refuge and fire prevention plans for evacuation (A) not very different in importance.

As regards the items in the lower layer of the firefighting facility operation inspection results (B), the importance of inspecting the automatic fire detection system's operation (B.1) was shown to be the highest at 0.408, followed by that of inspecting the automatic fire extinguishing equipment's operation (sprinkler, etc.) (B.3) at 0.367, that of inspecting the evacuation instrument and utilization plan (B.4) at 0.127, and that of inspecting the indoor fire hydrants' operation (B.2) at 0.099. In short, the respondents considered the rapid detection of fire and early fire extinguishing more important, and indoor fire hydrants and evacuation instruments relatively less important. These results can be said to reflect the problems^(9),14) related to effectiveness of the rescue hose and descending lifeline, which are at present mainly installed in elderly care facilities, as pointed out in previous studies.

Meanwhile, from among the items in the lower layer of the fire brigade's possibility of fire-extinguishing activities (C) showing the lowest importance among the items in the upper layer, the importance of securing a firefighting mobilization

Figure 3. Global weight & priority in AHP survey (level 2).

route (C.1) was shown to be highest at 0.388, followed by that of fire engine mobilization time (C.2) at 0.364, that of fire brigade activity space around the building (C.3) at 0.160, and that of the possibility of expansion of combustion to adjacent buildings (C.4) at 0.088. Road conditions and distance to the fire brigade, which enable the fire brigade to arrive quickly, were considered important. From among the items in the lower layer of fire safety management and prevention (D) showing the second-highest importance among the items in the upper layer, the importance of regular fire suppression and evacuation drills (D.2) was shown to be the highest at 0.433, followed by that of inspection of facilities of firefighting, construction, electricity, and so on (D.3) at 0.306, and that of writing of and education on customized fire response manual (D.1) at 0.262. This means that the respondents found it important to establish response systems to fight actual fires through fire suppression and evacuation drills at normal times.

An examination of the overall importance of 15 sub-items (product of the importance of upper items and sub-items) (Figure 3) showed the overall importance of regular fire suppression and evacuation drills (D.2) to be the highest at 0.151, followed by adequacy of the establishment of the refuge path plan (A.3) at 0.118 (A.3) and critically ill patients' evacuation support plan (A.1) at 0.109.

Finally, the study presents the fire safety evaluation standards (draft) for long-term care hospitals for the elderly by importance of AHP analysis results evaluating the fire safety of long-term care hospitals for the elderly, as shown in Table 4. The scores of the evaluation items were based on 100 points overall importance, with the numbers after the decimal point rounded off for calculation.

5. Conclusion

This study is for establishing fire safety evaluation indices for long-term care hospitals for the elderly. It derives fire

Table 4. Fire Safety Evaluation Standards (Draft)

Evaluation list	Score
Evacuation assistance	11
Horizontal evacuation safety zone	9
Evacuation plan	12
Evacuation and fire prevention facilities	10
Check automatic fire detection system	5
Check the indoor fire hydrant	1
Check the sprinkler	4
Check the evacuation facilities	2
Fire depot road	4
Firefighter arrival time	4
Securing firefighting space	2
Fire spread adjacent building	1
Manual preparation and education	9
Fire drill	15
Check the firefighting system	11
Total	100

safety evaluation items for long-term care hospitals for the elderly, analyzes the importance and priorities of the evaluation items through an expert survey, and finally presents the fire safety evaluation indices.

From the findings of this study,

1) the importance ratios of the upper layer evaluation items for long-term care hospitals for the elderly are as follows: refuge and fire prevention plans for evacuation: 0.423; fire safety management and prevention: 0.349; inspection of firefighting facility operation: 0.121; and possibility of fire-extinguishing activities for the fire brigade: 0.107.

2) The importance (overall importance) ratios of the lower layer evaluation items were as follows: regular fire suppression and evacuation drills: 0.151; adequacy of the establishment of the refuge path plan: 0.118; and critically ill patients' evacuation support plan: 0.109.

3) Finally, fire safety evaluation standards (draft) for long-term care hospitals for the elderly were obtained by converting the overall importance ratios based on a full score of 100 points.

The results of this study can be used as base data for establishing fire safety evaluation standards for elderly care facilities. The study is meaningful in that it presents evaluation standards (draft) for the evaluation of elderly care facilities.

However, the fire safety evaluation standards (draft) presented here have a limitation in that the study considered the opinions of only 44 firefighting experts. Moreover, the study has a limitation in that it did not present any quantitative

method for the evaluation standards. The above fire safety evaluation standards can be taken as guidelines for evaluating the fire safety of elderly care facilities after considering the opinions of other experts as well and improving the indices through additional studies.

Acknowledgments

This work was supported by the National Research Foundation of Korea (NRF) grant (No. NRF-2018R1A2B3005951), which was funded by the Korean government (MSIT) & This paper was supported by the "National Fire Agency" R&D program (20016433).

References

1. Korean Convalescent Hospital Association, "2020 Long-term Care Hospital White Paper", <http://www.k-cha.co.kr/> (2021.06).
2. E. P. Lee, "Case Study: Analysis of the Causes for Many Casualties in a Mil-Yang Sejong Hospital Fire", *Journal of Science Criminal Investigation*, Vol. 14, No. 2, pp. 134-145 (2020). <https://doi.org/10.20297/jsci.2020.14.2.134>.
3. I. B. Jeon, "Calculation of Evacuation Time in Elderly Medical Welfare Facilities Using FDS and Pathfinder", Master's Thesis, Graduate School of Inha university (2019).
4. J. Chae, S. C. Woo and Y. Hasemi, "A Study of the Fire-Safety Improvement Plan for Elderly Care Facilities", *Crisisonomy*, Vol. 7, No. 2, pp. 57-74 (2011).
5. H. J. Park and Y. J. Lee, "A Study on ASET Elongation & Notification Time to Fire Stations for the Escape Safety of Aged Bedridden Patients in Elderly Long-term Medical Care", *Fire Science and Engineering*, Vol. 32, No. 4, pp. 50-59 (2018). <https://doi.org/10.7731/KIFSE.2018.32.4.050>.
6. J. B. Kim, "A Study on Safety Assessment of the Evacuation at the Aged Care Hospital", Master's Thesis, Graduate School of Dongshin University (2010).
7. J. S. Song, "A Study on Securing Refuge Area in Nursing Homes", Master's Thesis, Graduate School of Construction Engineering and Industry Kyonggi University (2015).
8. S. C. Kim, "A Study on the Improvement Plan of Fire Safety in Nursing Homes for the Elderly", Master's Thesis, The University of Seoul Graduate School (2017).
9. J. S. Park, "Study on the Appropriateness of Criteria for Fire Safety in Elderly Care Facility", *J. Korean Soc. Hazard Mitig.*, Vol. 17, No. 5, pp. 189-195 (2017). <https://doi.org/10.9798/KOSHAM.2017.17.5.189>.
10. J. H. Seo, "A Study on the Improvement of Fire Safety Management in a Medical Care Hospital", Doctoral Thesis,

- Graduate School of Mokpo National University (2015).
11. S. H. Jin, "A Study on the Improvement of the Night Fire Response Manual through the Analysis of Field Survey and Fire Risk in Elderly Facilities", Master's Thesis, Graduate School of Hoseo University (2017).
 12. Y. J. Kim, "A Study on the Reform of the Evacuation Planning System in the Nursing Home for the Elderly", Master's Thesis, The University of Seoul Graduate School (2008).
 13. W. J. Lee, "A Study on the Ways to Improve the Fire Safety for Nursing Home", Master's Thesis, Graduate School of Industry and Engineering Seoul National University of Science and Technology (2017).
 14. H. S. Yeom, "A Study on the Improvement of Evacuation Safety at Long-Term Care Hospitals & Sanatorium for Older Persons through Surveys", Master's Thesis, Graduate School of Pukyong National University (2020).
 15. R. Cote, G. Harrington, "NFPA 101 Life Safety Code Handbook Chapter 18/19 New and Existing Health Care Occupancies", Korean Fire Protection Association, pp. 587-703 (2018).
 16. J. H. Ryu, "Improvement plan of self-inspection checklist of firefighting facilities", Master's Thesis, Graduate School of Construction Engineering and Industry Kyonggi University (2017).
 17. E. J. Park, "A study on the Public Operating System of Fire Inspection", Master's Thesis, Graduate School of Pusan National University (2019).
 18. National Fire Agency, "Notice on self-inspection matters of firefighting systems, etc", Enforcement April 1, 2021 Fire Department Notice No. 2021-17 and March 25, 2021, partially amended, www.law.go.kr (2021).
 19. Korea Institute for Healthcare Accreditation, "Standard Guidelines for Certification Survey of 3rd-cycle Long-term Care Hospital", Published (2020.09.).
 20. T. L. Saaty, "How to Make a Decision: The Analytic Hierarchy Process", *Interfaces*, Vol. 24, No. 6, pp. 19-43 (1994). <https://doi.org/10.1287/inte.24.6.19>.
 21. Y. H. Kwoun, "An Empirical Study on Importance of Evaluation Factors for Improvement of Fire Emergency Medical Service -Focused on Fire Officer's Questionnaire", Doctoral Thesis, Graduate School of Myongji University (2014).
 22. E. S. Chung, "A Study on the Development of Risk Index for the Fire Risk Assessment of the Buildings", Doctoral Thesis, Graduate School of Myongji University (2008).