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A Study on Correlation between Apartment Site Firefighting Engineers' Construction and Performance-Testing Competence and As-Built Inspection in Korea

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Abstract:
This study is to analyze how competence of apartment site firefighting engineers in construction and performance-testing affects the as-built inspection and improve the competence of firefighting engineers in construction for successful as-built inspections. In summary, first, it was found that the construction competence of firefighting engineers had a positive effect on the as-built inspection. This result shows that no defects occur in the as-built inspection when the firefighting engineers' construction competence is excellent. The better the firefighting engineers' construction competence is, the better the result of the as-built inspection is. Second, male firefighting engineers' competence in construction was higher than female firefighting engineers' but the performance-testing competence of female firefighting engineers was higher than male firefighting engineers'. This result can be interpreted as follows. When examining analysis results of the competence in performance-testing, which is a process that usually takes a firefighting engineer 5 years of experience to be able to carry out, female firefighting engineers had better perception of performance-testing than male firefighting engineers. It shows that female firefighting engineers'competence in performance-testing has a positive effect on the as-built inspection. Third, age and career had a negative but not statistically significant effect. In case of occupation, it had a positive but not statistically significant effect. Finally, the performance-testing competence had a positive and statistically significant effect.

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I. Introduction

An apartment is a house with 5 or more floors [1]. Firefighting facilities are applied to each building in apartments and firefighting facilities are installed in accordance with each different area and floor. In terms of the as-built inspection of firefighting facilities installed in the apartment, the as-built inspection of indoor fire hydrants and sprinklers includes the inspection of fire hydrant indicator operation, the test and inspection of emergency power operation, etc. On the other hand, the as-built inspection of water spray fire extinguisher facilities and carbon dioxide fire extinguisher facilities includes the inspection of extinguisher operation by each area to be protected, the inspection of the emission indicator operation, the inspection of the siren alarm

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detection and the interoperability inspection among others. In terms of automated re-detection equipment and emergency public address equipment, visual alarms and audible alarms are inspected. Interoperability tests are usually carried out for the smoke control equipment in staircases and auxiliary rooms for special evacuation [2].

On the other hand, when the construction of an apartment is not completed due to an order and delivery schedule set by the client and the construction company and the schedule for the new owners of the apartment to move in to the apartment, the as-built inspection of firefighting facilities is performed urgently in some cases in order to obtain a certificate of as-built inspection. As a result, there is often a gap in the supervision of the firefighting facilities between the issuance of the as-built inspection certificate to the completion of construction. In case of fire during the time of using the building during this period, there is a possibility of damage to life and property because firefighting facilities are not working during this period.

In addition, studies should be made in order to improve the efficiency of as-built inspections by evaluating construction competence of apartment site firefighting engineers, thus preventing the inadequate construction or incomplete as-built inspections that threaten the safety of the apartment residents and securing the competitiveness of firefighting engineers whocan efficiently manage the site. Thus, this study is aimed to set standards for the apartment site firefighting engineers' construction and performance-testing competence and explore ways to reduce the risk of as-built inspections. Eventually, the purpose of this study is to secure competitiveness of as-built inspections and promote corporate growth by establishing an efficient system to evaluate firefighting engineers' construction competence.

II. Analysis on Previous Studies

There are studies on apartment site firefighting engineers' construction and performance-testing competence including "Identifying Factors Affecting Labor Productivity for Residential Fire Protection System Installation" of Oh, Jae-Hoon; Kim, Dae Young; Kim, Jae Sik and Huh, Young-Ki (2017) [3], "An Analysis on the Job Performance of Construction Manager and Its Improvement Measures" of Kim Min-Chan and Son Chang-Baek) [4] etc. Studies on the as-built inspection of firefighting facilities include "A Study on the Improvement of Fire and Marine Engineering Supervision System" carried out by Lee Jae-sung (2011) [5], "Research on Improvement of Completed Inspection of Fire and Marine Engineering Corporation" of Moon Je-Ahn (2018) [6] "A Study on the Entrance Room of Preventive Fire Service" conducted by Kim Kyung-beom (2008) [7] and "Research on the Improvement of Fire-fighting Corporation Supervision System" of Oh Sang-hwan (2014) [8].

As above, the existing studies mentioned the establishment of a specialized agency for the outsourcing system of subcontracting the as-built inspection of firefighting facilities and administrative procedures to submit a certificate of an as-built inspection at the time of approval of building use. In addition, it was suggested as a solution to the problem that the results of the as-built inspections carried out for firefighting facilities be reported. On the other hand, there was no analysis on the effect of apartment site firefighting engineers' construction and performance-testing competence on as-built inspections of the firefighting facilities. This study is intended to analyze the effect of the site firefighting engineers' construction and performance-testing competence on as-built inspections.

The existing studies mentioned the establishment of a specialized agency for the outsourcing system of subcontracting the as-built inspection of firefighting facilities and administrative procedures to submit a certificate of an as-built inspection at the time of approval of building use. In addition, it was suggested as a solution to the problem that the results of the as-built inspections carried out for firefighting facilities be reported. On the other hand, there was no analysis

on the effect of apartment site firefighting engineers' construction and performance-testing competence on as-built inspections of the firefighting facilities. This study is intended to analyze the effect of the site firefighting engineers' construction and performance-testing competence on as-built inspections.

III. Study Methodology

3.1 Study Hypotheses

The hypotheses in this study were set up as follows to investigate the factors of firefighting engineers' construction and performance-testing competence influencing the as-built inspection.

Hypothesis 1: The firefighting engineer's gender will make differences in the quality of as-built inspections.

Hypothesis 2: The firefighting engineer's age will have a negative effect on the quality of as-built inspections.

Hypothesis 3: The firefighting engineer's experience will have a negative effect on the quality of as-built inspections.

Hypothesis 4: The firefighting engineer's occupation will have a positive effect on the quality of as-built inspections.

Hypothesis 5: The firefighting engineer's construction competence will have a positive effect on the quality of as-built inspections.

Hypothesis 6: The firefighting engineer's performance-testing competence will have a positive effect on the quality of as-built inspections.

3.2 Study Tools

The study tools used in this study consisted of 5 questions about firefighting engineers' construction competence, 3 questions as to firefighting engineers' performance-test competence, 4 questions in regard to things necessary for the as-built inspection of fire protection facilities and 7 questions concerning the general characteristics of the subjects in this study. These questions had been organized into a structured questionnaire.

3.2.1 Control Variables: Personal Characteristics of Firefighting Engineers

Control variables in this study are personal characteristics of firefighting engineers. Specifically, the measurement areas by gender, age, work experience, position, salary level, and occupation that would have an effect on the as-built inspections were put into the variables. These variables were organized into 7 questions.

3.2.2 Independent Variable: Firefighting Engineers' Construction Competence

The independent variable in this study is firefighting engineers' construction competence. The questionnaire which measures the effect of firefighting engineers' construction competence on the as-built inspection is organized with 4-point Likert scales. The specific tools to measure the effect are questions as to the firefighting engineers' apartment construction experience, their head office's support, practical education and training they received, when to submit firefighting as-built documents and whether they had received the progress payment and labor cost or not. These things which actually affect the competence of the firefighting engineers in construction are organized into 5 questions. Each question is measured with a 4-point Likert scale (from "1" meaning "not at all" to "4" meaning "very much"). The higher the score, the higher the competence of the firefighting engineer in construction. It showed that Cronbach's alpha = .862 in these questions.

3.2.3 Dependent Variable: As-Built Inspection

The dependent variable in this study is the as-built inspection. The measurement areas of the effect on as-built inspections consisted of 4 questions including the site construction management system, setbacks for as-built inspection schedules, firefighting facilities that were malfunctioning or not installed at all and firefighting supplies that were missing or left out. Each question is measured with a 4-point Likert scale. The higher the score is, the

higher the quality of the as-built inspection is. It showed that Cronbach's alpha = .736 in these questions.

3.2.4 Independent Variable: Firefighting Engineers' Performance-Testing Competence

The independent variable in this study is firefighting engineers' performance-testing competence. The questionnaire which measures the effect of the firefighting engineers' performance-testing competence on the as-built inspection is organized with 4-point Likert scales. The specific tools to measure the effect are questions about the problems of fire door installation, the confusion over the construction period of each discipline and a delay of the performance test. These things which actually affect the performance-testing competence of the firefighting engineers are organized into 3 questions. Each question is measured by a 4-point Likert scale (from "1" that means "not at all" to "4" that means "very much"). The higher the score is, the higher the firefighting engineer's performance-testing competence is. It showed that Cronbach's alpha = .777 in these questions.

IV. Data collection and analysis methods

The data for this study were collected from July 1, 2019 to July 31, 2019. The providers of these data were the people relevant to this study such as firefighting officers, firefighting construction supervisors, firefighting facility designers, firefighting facility operators and maintainers, firefighting facility contractors and clients (owners and superintendents). The data were collected after distributing the questionnaire through social media, direct visits, fax, interviews, written surveys and email distribution. At the nearby construction sites, the questionnaire was outlined and an explanation of the purpose of the survey was given to the respondents. The questionnaire was distributed to 400 people and 378 copies were collected. The collected copies were analyzed twice and questionnaire copies with answers irrelevant to the questions were excluded. Finally, 360 questionnaire copies were analyzed.

Data collected in this study were analyzed using SPSS WIN 25 program. Frequency, factor and reliability analyses were carried out first with a concrete empirical analysis method on the effect of the study subjects' general characteristics and site firefighting engineers' construction and performance-testing competence on the as-built inspection. In addition, correlation analysis was performed through the refinement process of variables. Finally, the hypothesis was tested by hierarchical regression analysis.

V. Findings and Discussions

5.1 Basic Statistics Analysis

In this study, personal factors are the first to be reviewed and interpreted. This is because it helps infer what effect the answers of the questionnaires had on the as-built inspection to identify the respondents' personal factors.

In terms of demographic characteristics, male respondents accounted for 87.5 % and female respondents accounted for 12.5 %. It showed a high proportion of male respondents. It seems to depend on the conditions of apartment construction sites where firefighting engineers were mobilized. In terms of the age group, respondents in their 40s (from 40 to 50 years of age) accounted for 42.2 %, which was the highest ratio. Respondents in their 50s and 60s (from 50 to 70 years of age) accounted for 20.8 % and respondents in their 30s (from 30 to 40 years of age) accounted for 20%. Finally, respondents under their 30s (30 years of age or younger) accounted for 16.9 %. In terms of their careers, experience of 10 to 20 years accounted for 45 %, which was the highest ratio and followed by experience more than 20 years. This accounted for 25.6 %, which was the second highest ratio and experience of 5 to 10 years accounted for 17.8 %. Finally, experience less than 5 years accounted for 11.7 %. It reflected the high level of experience that the firefighting officers' group, firefighting

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supervisors' group and firefighting designers' group had. In terms of the position in the private sector excluding firefighting officers, executive or higher positions accounted for 28.3 %. It was the highest ratio and this was followed by department head, office head and team leader positions,

which accounted for 25.35 %. Finally, the employee, manager and deputy general manager positions accounted for 21.1 %. When it comes to the position of firefighting officers, firefighter, senior firefighter and fire sergeant positions accounted for 9.7 % and the fire lieutenant position accounted for 9.2 %. Also, the fire captain position accounted for 6.1 %. Finally, deputy fire chiefs accounted for 0.3 %. In the case of their income, 3 million won or more accounted for 53.6 %, which was the highest ratio. Income from 2.5 to 3 million won accounted for 25.6 %. Income from 2 million to 2.5 million won accounted for 13.9 % and income less than 2 million won accounted for 6.9 %. In general, 3 million won or more accounted for more than half of the answers and the firefighting officers' income was the highest. It was followed by the client company employees' income, firefighting design or supervision company employees' income and firefighting facility contractor employees' income. In terms of the occupation, the firefighting officers and firefighting facility contractors accounted for 25.3 %, respectively. It was the highest ratio. Firefighting designers and supervisors accounted for 25 %. Also, clients (owners and superintendents) accounted for 24.4 %. The results of this frequency analysis by these general characteristics of the study subjects are shown in Table 1.

Table 1. Basic Statistics Analysis of Study Subjects
N = 360

Variable	Classification	Frequency (N)	Ratio (%)
Gender	Male	315	87.5
	Female	45	12.5
Age	≤ 30	61	16.9
	30 ~ 40	72	20
	40 ~ 50	155	42.2
	50 ~ 70	72	20.8
Career	≤ 5	42	11.7
	5 ~ 10	64	17.8
	10 ~ 20	162	45
	≥ 20	92	25.6
Position	Employees, managers and deputy general managers	75	21.1
	Department heads, office heads and team leaders	92	25.3
	Executives or higher	102	28.3
	Firefighters, senior firefighters and fire sergeants	35	9.7
	Fire Lieutenants	33	9.2

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	Fire Captains	22	6.1
	Deputy fire chiefs or higher	1	.3
Monthly income	≤ 200	25	6.9
	200 ~ 250	50	13.9
	250 ~ 300	92	25.6
	≥ 300	193	53.6
Occupation	Firefighting officers	91	25.3
	Firefighting designers, supervisors and operators and maintainers	90	25
	Firefighting facility contractors	91	25.3
	Clients	88	24.4
Duty	Firefighting officers	91	25.6
	Operating and maintenance managers	54	15
	Cost and schedule managers	55	15.3
	Construction managers	90	25
	Project managers	70	19.2

5.2 Correlation Analysis between Construction and Performance-testing Competence and As-Built Inspections

A correlation analysis was conducted to analyze the relationships among the factors in this study. A correlation analysis is to analyze the correlation coefficient which means the strength and direction of how one variable changes as another variable changes when there are two or more variables. If the correlation coefficient is 0 or more, the positive correlation is strong. If the correlation coefficient is 0 or less, the negative correlation is strong. The construction competence is a cause of as-built inspections and has a greatest effect (r = .594 and p <.001) on as-built inspections. Therefore, the construction competence is considered to have a positive correlation with as-built inspections. However, the performance-testing competence did not have a significant correlation with the construction competence or as-built inspections. Thus, the higher the construction competence and performance-testing competence, the higher the quality of as-built inspections. The analysis results are shown in Table 2.

Table2. Correlation Analysis between Construction Competence and As-Built Inspections
N = 360

Classification	**Correlation analysis**		
	Construction competence	**Performance test**	**As-built Inspection**
Construction competence	1		
Performance-testing competence	.043	1	
As-built Inspection	.594***	.027	1
*** The correlation is significant at the 0.001 level (both sides)		*p < .05, **p < .01 and *** p < .001	

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5.3 Effect of Personal Factors and Construction and Performance-Testing Competence on As-Built Inspections (Hierarchical Regression Analysis)

In this study, the causal relationship between the apartment site firefighting engineers' construction and performance-testing competence and as-built inspections was examined and their performance-testing competence was added to the independent variable. In the first model, the effect of gender, career and occupation by personal characteristics on as-built inspections was examined. In the second model, the effect construction competence had on as-built inspections was verified. In the third model, the effect of the performance-testing competence on as-built inspections was tested. As a result, the relationship between the three variables was examined by analyzing variation and significance of the values representing explanatory power, independent variables and regression coefficients of each model. In addition, categorical variables, such as gender, age, career and occupation were converted into dummiesand put into the analysis. The overall analysis results of the models are shown in Table 3.

5.4 Effect of Age, Career and Occupation on As-Built Inspections

Model 1 shows the test results of the effect which the age, career and occupation of the respondents in this study had on as-built inspections. The results of the significance test were as follows. The age had a negative effect on the as-built inspection but no statistically significant effect (β -.009 p > .05). In addition, the career had a negative effect on the as-built inspection but had no statistically significant effect (β -.083 p > .05). On the other hand, the occupation had a positive but not statistically significant effect on the as-built inspection (β = .036 p > .05). The regression analysis model was significant at the level of p < .05. The explanatory power of this model was .011, indicating that the age, career and occupation explained 1.12 % of the as-built inspection and the value that signified the explanatory power above was Adj R2, which was .002, showing that these independent variables' effect on the as-built inspection was no more than 0.2 % and that the explanatory power seems to be low. This shows that the control variables which are the factors of age, career and occupation related to the as-built inspections do not act as variables. On the other hand, D - W = 1.938, which was close to 2. It was deemed suitable to assume independence of standardized residuals. The variation index factor was also less than 10, indicating no multicollinearity issues.

5.5 Effect of Age, Career, Occupation and Construction Competence on As-Built Inspection

Model 2 shows the test results of the effect which the age, career, occupation and construction competence of the respondents in this study had on as-built inspections. The results of the significance test were as follows. A variable which explains the significance level well was the construction competence (β .596 p <.05). This variable was found to have a positive effect on the as-built inspection and it was a statistically significant effect. This result shows that no defects occur in the as-built inspection when the firefighting engineers' construction competence is excellent. The better the firefighting engineers' construction competence is, the better the result of the as-built inspection is. The age had a positive effect on the as-built inspection but no statistically significant effect (β .87 p > .05). The occupation had a positive effect on the as-built inspection but no statistically significant effect (β .029 p > .05) but their career had a negative but not statistically significant effect on the as-built inspection (β -.086 p > .05). The regression analysis model was significant at the level of p < .001. The explanatory power of this model was .357, indicating that their age, career and occupation explained 35.7 % of the as-built inspection and the

value which signified the explanatory power above was Adj R2, which was .349. It indicated that the effect of the independent variables on the as-built inspection was only 34.9 % and that the explanatory power seems to be low. This shows that the control variables which are the factors of age, career and occupation related to the as-built inspections do not act as variables. On the other hand, D-W = 1.938, which is close to 2. It was considered suitable to assume independence of standardized residuals. The variation index factor was also less than 10, indicating no multicollinearity issues.

5.6 Effect of Age, Career, Occupation and Performance-testing Competence on As-Built Inspections

Model 3 shows the test results of the effect which the age, career, occupation, construction competence and performance-testing competence of the respondents in this study had on as-built inspections. The results of the significance test were as follows. A variable which explains the significance level well was the construction competence (β .595 p <.05). The construction competence was found to have a positive effect on the as-built inspection and it was a positive and statistically significant effect. This result shows that no defects occur in the as-built inspection when the firefighting engineers' construction competence is excellent. The better the firefighting engineers' construction competence is, the better the result of the as-built inspection is. Secondly, the results of the significance test were also as follows. A variable which explains the significance level well was the performance-testing competence (β .003 p <.05). The performance-testing competence was found to have a positive effect on the as-built inspection and this was also a statistically significant effect. In terms of the competence in performance-testing, which is a process that usually takes a firefighting engineer 5 years of experience to carry out fully, it indicated that the better firefighting engineers' construction competence, the better their competence in performance-testing. In other words, the better improved and the more excellent the firefighting engineers' competence in performance-testing, the higher the issuance rate of as-built inspection certificates certifying that no defects occurred during the as-built inspections. In addition, it was found that the better apartment site firefighting engineers' performance-testing competence for fire-fighting facility construction, the more excellent the result of the as-built inspection. The age had a positive effect on the as-built inspection but no statistically significant effect (β .087 p > .05). The occupation had a positive effect on the as-built inspection but no statistically significant effect (β .028 p > .05) but their career had a negative but not statistically significant effect on the as-built inspection (β -.087 p > .05). The regression analysis model was significant at the level of p < .001. The explanatory power of this model was .357. It indicated that factors of the age, career and occupation and the construction and performance-testing competence explained 35.7 % of the as-built inspection. The value that signified the explanatory power above was Adj R2, which was .347. This indicated that the independent variables' effect on the as-built inspection was 34.7 %. The explanatory power seems to be low. This may be because a lot of variables of as-built inspections were left out. On the other hand, D - W = 1.938, which was close to 2. It was deemed suitable to assume independence of standardized residuals. The variation index factor was also less than 10, indicating no multicollinearity issues. When making a comparison among the magnitudes of the standardized coefficients, which was an evaluation of relative effects, the effect of the construction competence on the as-built inspection was the largest (β = .595), followed by the performance-testing competence (β = .003).

Table 3. Hierarchical Regression Analysis of Effect of Personal Factors and Competence in Construction and Performance-Testing on As-Built Inspection

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N = 360

Classification		Model 1				Model 2				Model 3				VIF
Dependent variable	Independent variable	Personal factors → as-built inspections				Personal factors and construction competence → as-built inspections				Personal factors and construction and performance-testing competence → as-built inspections				
		B	β	t	p	B	β	t		B	β	t	P	
As-built Inspection	(Constant)	2.826		98.393	.000	1.761		21.872	.000	1.755		15.438	.000	
	Age	-.010	-.009	-.105	.916	.098	.087	1.265	.207	.098	.087	1.266	.206	2.575
	Career	-.109	-.083	-.976	.329	-.114	-.086	-1.262	.208	-.115	-.087	-1.261	.516	2.588
	Occupation	.035	.036	.675	.500	.028	.029	.664	.507	.028	.028	.651	.516	1.040
	Construction competence					.359	.596	13.813	.000	.359	.595	13.771	.000	1.026
	Performance-testing competence									.002	.003	.079	.000	1.028
Statistics		R^2=.011 adjusted R^2= .002 F = 1.280 and p = .037b				R^2=.357 adjusted R^2=.349 F = 49.169 and p = .000c				R^2=.357 adjusted R^2= .347 F = 39.226 and p = .000d D - W = 1.938				

VI. Conclusions

The purpose of this study was to analyze the effect of the site firefighting engineers' construction and performance-testing competence on as-built inspections. To this end, the comparative analysis was carried out based on the result of the questionnaire survey on the construction competence and the performance-testing competence of the firefighting engineers and the result of the as-built inspection survey and the correlations and causal relationships were tested by a statistical analysis program. The results are as follows.

First, the competence of the firefighting engineers in construction was found to have a positive effect on the quality of the as-built inspection. This result shows that no defects occur in the as-built inspection when the firefighting engineers' construction competence is excellent. The better the firefighting engineers' construction competence is, the better the result of the as-built inspection is.

Second, age and career had a negative but not statistically significant effect. In case of occupation, it had a positive but not statistically significant effect.

Third, male firefighting engineers' competence in construction was higher than female firefighting

engineers' but the performance-testing competence of female firefighting engineers was higher than male firefighting engineers'. This result can be interpreted as follows. When examining analysis results of the competence in performance-testing, which is a process that usually takes a firefighting engineer 5 years of experience in the firefighting facility construction to be able to carry out fully, female firefighting engineers had the higher level of perception of performance-testing than male firefighting engineers. It shows that female firefighting engineers' performance-testing competence has a positive effect on the as-built inspection.

Finally, the performance-testing competence of firefighting engineers had a positive and statistically significant effect. In terms of the competence in performance-testing, which is a process that usually takes a firefighting engineer 5 years of experience to carry out fully, these results indicated that the better the firefighting engineers' competence in construction, the better their competence in performance-testing. In other words, the better improved and the more excellent the firefighting engineers' competence in performance-testing, the higher the issuance rate of as-built inspection certificates certifying that no defects occurred during the as-built inspections. In addition, it was found that the better apartment site firefighting engineers' performance-testing competence for fire-fighting facility construction, the more excellent the result of the as-built inspection.

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