

A Study on Influence and Mediating Effects of Apartment Firefighting Engineers' Design Competence and Building Permit on the As-Built Inspection in Korea

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Abstract:

This study analyzed the mediating effect that a building permit has on apartment firefighting engineers' design competence and as-built inspections. The analysis results are as follows. First, it was found that the design competence of firefighting engineers had a positive effect on the approval for the building permit. This means that a building permit is approved well if firefighting engineers with excellent design competence design the firefighting facilities to satisfy the national fire safety standards. Second, it was found that the design competence of firefighting engineers had a positive effect on as-built inspections. The higher the completeness of design drawings and documents prepared by the firefighting engineers is, the more positive its effect on the quality of the as-built inspections is. Third, the approval for the building permit was found to have a mediating effect on firefighting engineers' design competence and as-built inspection. The building permit approval which was a parameter did not only have a positive and statistically significant effect on firefighting engineers' design competence that was an independent variable but the as-built inspection which was a dependent variable. This result means not only that a building permit gets approved well but also that the quality of as-built inspections is improved when firefighting engineers design firefighting facilities in accordance with the national fire safety standards by using their excellent design competence, in order to prevent inadequate preparation of design drawings and documents and avoid frequent design changes.

Keywords: Apartment, Design competence, As-built inspection, Building permit, Mediating effect

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Introduction

Fires in apartments with rapid and widespread combustion and smoke spreads can lead to personal and property damage, if not extinguished initially. Public apartments' firefighting facilities are designed by successful bidders. Private apartments' firefighting facilities are designed by subcontractors as per terms and conditions of subcontracts prepared by clients (owners and

contractors). Clients contract with architectural design offices to design all buildings and facilities including firefighting facilities. The firefighting facility design scope is subcontracted to subcontractors. Sub-subcontracting and low-cost subcontracting are causing quality deterioration and poor design. This reality acts as a drag on qualitative growth of the firefighting discipline. The quality of the firefighting facilities in buildings

can be deteriorated due to the poor design of firefighting facilities. This can lead to poor quality of life for people. It is necessary to establish the infrastructure for firefighting facility design in order to improve safe quality of life for people [1]. Particularly, the legal firefighting facilities in 268 buildings (61 %) of 440 buildings newly constructed in Seoul and Busan with firefighting facilities installed on a large scale surveyed on June 18, 2019 to see whether the as-built inspections of the buildings had been carried out properly, were found to be damaged, broken or not even installed at all. Although firefighting facilities were not properly installed as per firefighting design drawings and documents, it was found that the as-built inspections had been carried out and the buildings were approved for use [2]. It is necessary to reconsider the survey as an opportunity to strengthen fire safety of apartments and prevent fires by inspecting the firefighting supplies for the appropriateness of their installation or damage, including firefighting supplies that are misidentified in firefighting design drawings or documents, left out during installation or interfering with each other's area to protect. In addition, it is necessary to confirm if the firefighting design drawings and documents have been prepared as per the national fire safety standards to ensure that the building permits would be approved well and if the as-built inspection of firefighting facilities has been made as per firefighting facility installation plans [3].

In this study, it is postulated that the achievement of firefighting engineers' competitiveness whereby effective management on site is ensured should precede the prevention of poor design, frequent changes of design, poor as-built inspections, etc. which threaten the fire safety of the apartments. The purpose of this study is to improve the quality of as-built inspections by improving the apartment site firefighting engineers' design competence.

Analysis on Previous Studies

Previous studies on the influence of apartment site firefighting engineers' design competence on the as-built inspection and mediating effects of a building permit are as follows. In a study on the firefighting engineers' design competence, Oh Sang-hwan (2014) proposed that the burden of the construction costs can be reduced by the firefighting engineers, preparing the design drawings and documents in close interdisciplinary consultation with designers of the other disciplines from the stage of engineering design to the delivery of design drawings and documents for construction, thereby improving the completeness of design drawings and documents and minimizing some missing details of firefighting facilities [4]. In a study on the firefighting engineers' design and supervision system, Lee Hyun Sang (2017) proposed that strengthened design and supervision law as strong as other laws be introduced to solve the problems resulting from frequent design changes in each process of firefighting facility construction due to poor design which did not take into consideration the site condition of apartment houses [5]. In a study on the as-built inspection of fire-fighting facilities, Moon Je-Ahn (2018) suggested that the as-built inspection certificate be excluded from the dossier submitted for approval but be attached to it when the building was approved for use after completing firefighting facility construction [6]. Kim Kyung-beom (2008) also proposed a plan to contract with private subcontractors to carry out the building permit approval and the as-built inspections if the scope of work had relatively weak characteristics of public goods but required characteristics of a market and expertise [7].

As such, studies on mediating effects of site firefighting engineers' design competence on the building permit approval and as-built inspections are insufficient. Therefore, this study intends to analyze mediating effects of site firefighting

engineers' design competence on the building permit approval and as-built inspections.

Study Hypotheses and Tools

The hypotheses in this study were set up as follows in order to investigate the mediating effects of site firefighting engineers' competence in design on the building permit approval and as-built inspection by examining previous studies.

Hypothesis 1: The firefighting engineer's design competence will have an effect on the approval for the building permit.

Hypothesis 2: The firefighting engineer's design competence will have an effect on the as-built inspection.

Hypothesis 3: The approval for building permit will have a mediating effect on the firefighting engineer's design competence and the as-built inspection.

The tools used in this study were control variables shown in Table 1. They consisted of 8 questions to identify personal characteristics, 4 questions in regard to firefighting engineers' design competence, 2 questions about the approval for the building permit and 2 questions of matters necessary for the as-built inspection.

Table 1. Composition of Study Tools

| Classification | Question Content | Question | Cronbach's alpha |
|------------------------------|--|-----------------------------------|------------------|
| Personal Characteristics | - Gender - Age - Working experience - Position - Salary - Occupation - Construction type | 1 ~ 8 | .777 |
| Design Competence | - Poor preparation of design drawings and documents - Cause of poor construction - Prevention of frequent design changes - Strengthened responsibility for building permit approval | 9 ~ 12 (Likert 4-point scale) | .862 |
| Approval for Building Permit | - Necessity of introducing the same design system as other disciplines - Review of the design of firefighting facilities as per the national fire safety | 13 ~ 14 (Likert 4-point scale) | .736 |
| As-built Inspection | - Site construction management system - TAB as-built inspection schedule | 15 ~ 16 (Likert 4-point scale) | .736 |

Data Collection and Analysis Methods

4.1 Data Collection

The data for this study were collected from August 1, 2019 to August 31, 2019. The providers of these data were the persons 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 360 people and 325 copies were collected. The collected copies were analyzed twice and questionnaire copies with answers irrelevant to the questions were excluded. Finally, 311 questionnaire copies were analyzed.

4.2 Analysis Method

Data collected in this study were analyzed using SPSS WIN 25 program. First of all, frequency analysis, factor analysis and reliability analysis as per the questionnaire were conducted as a concrete empirical analysis method to investigate the general characteristics of the study subjects, the effect of the apartment site firefighting engineers' design competence on the as-built inspection and the mediating effect of the approval for the building permit. In addition, correlation analysis was performed through the refinement of variables. The hypotheses were tested by hierarchical regression analysis after converting the variables into dummies.

Findings and Discussions

5.1 Basic Statistics Analysis

Basic statistics analysis is shown in Table 2. In terms of their gender, male respondents accounted for 75.9 % and female respondents accounted for 24.1 %. In terms of their age, the respondents in their 40s (from 40 to 50 years of age) accounted for 45.7 %, which was the highest ratio, and the respondents under their 30s (30 years of age or younger) accounted for 11.6 %, which was the lowest ratio. In terms of their working experience, respondents with the experience of 10 to 20 years accounted for 46 % and respondents with the experience less than 5 years accounted for 11.6 %. In the terms of their positions in the private sector, the executive or higher positions accounted for 34.4%, which was the highest ratio and followed by department head, office head and team leader positions accounting for 28 %. Employees, managers and deputy general managers accounted for 21.1 %. When it came to the firefighting officers' positions, fire lieutenants accounted for 11.9 %, which was the highest ratio. It was followed by the fire captain position which accounted for 9 % and the deputy fire chief or higher positions which accounted for 0.6 %. In the case of their income, 3 million won or more accounted for more than half of the answers.

Table 2. Basic Statistics Analysis of Study Subjects

N = 311

| Variable | Classification | | Frequency (N) | Ratio (%) |
|----------|----------------|--|---------------|-------------|
| Gender | Male | | 236 | 75.9 |
| | Female | | 75 | 24.1 |
| Age | ≤ 30 | | 36 | 11.6 |
| | 30 ~ 40 | | 54 | 17.4 |
| | 40 ~ 50 | | 142 | 45.7 |
| | 50 ~ 70 | | 79 | 25.4 |
| Career | ≤ 5 years | | 36 | 11.6 |
| | 5 ~ 10 years | | 51 | 16.4 |
| | 10 ~ 20 years | | 143 | 46 |
| | ≥ 20 years | | 81 | 26 |
| Position | Private Sector | Employees, managers/deputy general managers | 31 | 10 |
| | | Department heads, office heads/team leaders | 87 | 28 |
| | | Executives or higher | 107 | 34.4 |
| | | Subtotal | 225 | 72.4 |
| | Firefighting | Firefighters, senior firefighters and fire sergeants | 19 | 6.1 |

| | | | | |
|----------------|---------------------|------------------------------|-----------|-------------|
| | officers | Fire Lieutenants | 37 | 11.9 |
| | | Fire Captains | 28 | 9.0 |
| | | Deputy fire chiefs or higher | 2 | 0.6 |
| | | Subtotal | 86 | 27.6 |
| Monthly income | ≤ 2 million won | | 28 | 9 |
| | 2 ~ 2.5 million won | | 34 | 10.9 |
| | 2.5 ~ 3 million won | | 91 | 29.3 |
| | ≥ 3 million won | | 158 | 50.8 |

5.2 Influence of Apartment Firefighting Engineers' Design Competence on As-built Inspection and Mediating Effects of Approval for Building Permit (Correlation Analysis)

Correlation analysis is to analyze the relationships between factors and the correlation between firefighting engineers' design competence and building permit approval (independent variables) is $r = .280$, $p = .000$ and $p < .05$. The significance test shows that the significance probability is less than .05. It can be regarded as a significant correlation. The correlation coefficient is also positive. The correlation between the design competence and as-built inspection is $r = .248$, p

$< .001$ and $p < .05$. The significance test shows that the significance probability is less than .05. It can be regarded as a significant correlation. The correlation coefficient is greater than 0, indicating a positive correlation. The approval for the building permit that is a parameter can be considered to have a statistically significant correlation with the as-built inspection that is a dependent variable since the significant probability is less than .05 ($r = .202$, $p = .000$ and $p < .05$). The correlation coefficient is greater than 0, indicating a positive correlation. The analysis results are shown in Table 3.

Table 3. Influence of Firefighting Engineers' Design Competence on As-built Inspection and Mediating Effects of Approval for Building Permit (Correlation Analysis)

N = 311

| Classification | Correlation analysis | | |
|--------------------------|----------------------|--------------------------|---------------------|
| | Design Competence | Building Permit Approval | As-Built Inspection |
| Design Competence | 1 | | |
| Building Permit Approval | .280** | 1 | |
| As-Built Inspection | .248** | .202** | 1 |

*** The correlation is significant at the 0.01 level (both sides). * $p < .05$, ** $p < .01$ and *** $p < .001$

5.3 Influence of Apartment Firefighting Engineers' Design Competence on As-built Inspection and Mediating Effects of Approval for Building Permit (Hierarchical Regression Analysis)

The causal relationship between the influence of apartment site firefighting engineers' design competence on the as-built inspection and the

mediating effect of the building permit approval was examined. In the first stage, the effect of apartment site firefighting engineers' personal characteristics and design competence on the building permit approval that was a parameter was examined. In the second stage, the effect of the firefighting engineers' personal characteristics and design competence on the as-built inspection was examined. In the third

stage, the building permit approval's mediating effect on the influence of the firefighting engineers' personal characteristics and design competence on the as-built inspection was tested. As a result, the causal relationship among three variables was examined by analyzing variation and significance of

significance probability, independent variables, explanatory power and regression coefficients as to each model. The overall analysis results of the models are shown in Table 4.

Table 4. Hierarchical Regression Analysis on Mediating Effects of Building Permit Approval Based on Influence of Personal Characteristics and Firefighting Engineers' Design Competence on As-built Inspection
N = 311

| Classification | Stage 1 (Design Competence > Building Permit Approval) | | | | Stage 2 (Design Competence > As-Built Inspection) | | | | Stage 3 (Design Competence, Building Permit Approval and As-Built Inspection) | | | | VIF | |
|--------------------------|--|---------|-------|-------|--|---------|-------|-------|--|---------|-------|-------|-------|-------|
| | B | β | t | p | B | β | t | p | B | β | t | P | | |
| (Constant) | 2.079 | | 7.742 | .000 | 1.613 | | 4.248 | .000 | 1.217 | | 2.949 | .003 | | |
| Personal Characteristics | Gender | .012 | .011 | .155 | .877 | .127 | .081 | 1.175 | .241 | .125 | .079 | 1.163 | .246 | 1.599 |
| | Age | .059 | -.074 | 1.201 | .231 | .012 | .016 | .241 | .809 | .001 | .001 | .013 | .990 | 1.279 |
| | Career | -.039 | -.076 | -.991 | .322 | .038 | .053 | 0.694 | .488 | .046 | .063 | .832 | .406 | 1.962 |
| | Salary | .021 | .043 | .493 | .622 | -.005 | -.007 | -.084 | .933 | -.009 | -.013 | -.152 | .879 | 2.515 |
| Design | .212 | .255 | 4.465 | .000 | .256 | .218 | 3.824 | .000 | .216 | .184 | 3.145 | .000 | 1.097 | |
| Mediator | .191 | .134 | 2.360 | .022 | | | | | | | | .000 | 1.086 | |
| Statistics | R ² =.100 adjusted R ² =.076 F = 4.199 p = .000b | | | | R ² =.105 adjusted R ² =.081 F = 4.428 p = .000b | | | | R ² =.121 adjusted R ² = .095 F = 4.614 p = .000b D - W = 1.456 | | | | | |

p<.05, **p<.01 and ***p<.001

5.3.1 Effect of Apartment Firefighting Engineers' Design Competence on Building Permit Approval

The first stage shows the test results of the effect of design competence which is an independent variable on the approval for the building permit. The regression analysis model is significant at the level of $p < .05$ and the explanatory power of the model is .100. It indicates that the competence in design which is an independent variable explains 10 % of the approval for the building permit which is a parameter. The value which signifies the explanatory power above is Adj R² and is 0.76, indicating that the effect of the design competence that is an independent variable on the approval for the building permit which is a parameter, is no more than 7.6 % and the explanatory power is low. This

may be because a large number of variables related to the approval for the building permit have been left out. The results of the significance test were as follows. In terms of the control variables' specific effect, gender ($\beta = .011$ and $p > .05$), age ($\beta = -.074$ and $p > .01$) and career ($\beta = -.076$ and $p > .05$) that were the personal characteristics were analyzed as variables which did not have a significant effect on the approval for the building permit. In the case of the design competence, it had a positive effect on building permit approval which was a parameter. In this case, it had a statistically significant effect ($t = 4.465$ and $p = .000$). It is found about the effect of the design competence that the better the design of apartment firefighting facilities satisfies the national fire safety standards and the more excellent the firefighting engineers' competence in design is, the better the building permit is approved. This proved

the first study question, "The firefighting engineer's design competence will have an effect on the approval for the building permit." It was proved by Lee, Hyun Sang (2017) that the design competence of apartment site firefighting engineers affected the building permit approval. He proved that poor competence of these firefighting engineers in design affected the frequent disapproval of the building permits. For this reason, he considered that the fewer the firefighting facilities left out in the design drawings and documents were and the less often the design changes that were made on site were, the better the building permits were approved.

5.3.2 Effect of Apartment Firefighting Engineers' Design Competence on As-Built Inspection

The second stage shows the test results of the effect of design competence which is an independent variable on the as-built inspection. The regression analysis model is significant at the level of $p < .05$ and the explanatory power of the model is .100 and this indicates that the design competence that is an independent variable explains 10 % of the as-built inspection which is a dependent variable. This is signified by Adj R^2 and the value is 0.81. It indicates that the effect which the design competence that is an independent variable has on the approval for the building permit which is a parameter is only 8.1% and the explanatory power is low. This may be because a lot of variables of the as-built inspection which is an independent variable were left out. The results of the significance test were as follows. In terms of the control variables' specific effect, gender ($\beta = .081$ and $p > .05$), age ($\beta = -.016$ and $p > .05$) and career ($\beta = .053$ and $p > .05$) that were the personal characteristics were analyzed as variables that did not have a significant effect on the as-built inspection. In the case of design competence, it was found to have a positive effect on the as-built inspection that is a dependent variable. The effect of the design competence was found to be statistically significant ($t = 3.824$ $p = .000$). For this reason, the design competence was found to satisfy the test conditions. It showed not only that the poor design competence or poor design that had not taken into consideration the site conditions led to the frequent design changes each firefighting facility construction process of actual apartment construction site situation but that poor completeness of design drawings and documents

affected the quality of the as-built inspection. The higher the completeness of design drawings and documents prepared by the firefighting engineers is, the more positive its effect on the quality of the as-built inspections is. These results show that the quality of the as-built inspection is improved when the firefighting engineers' design competence is good. This proved the second study question, "The firefighting engineer's design competence will have an effect on the as-built inspection." Oh Sang-hwan (2014) proved that the design competence which was an independent variable had a positive effect on the as-built inspections and he confirmed in his previous study that the better the completeness of the design drawings and documents improved through close interdisciplinary consultation with the designers of the other disciplines from the stage of engineering design to the delivery of design drawings and documents for construction and the fewer the missing details and the lack of firefighting facilities, the more positive its effect on the quality of as-built inspections.

5.3.3 Mediating Effects of Approval for Building Permit on Firefighting Engineers' Design Competence and As-Built Inspection

In the third stage, the design competence, building permit approval and as-built inspections are all included and the regression analysis model is significant at the level of $p < .05$. The explanatory power of the model is .121, indicating that competence in design which is an independent variable explains 12.1 % of building permit approval that is a parameter. It is signified by Adj R^2 , which is .095 and it indicates that the effect of the design competence which is an independent variable and the approval for the building permit that is a parameter on the as-built inspection that is a dependent variable, is about 9.5 %. Therefore, the explanatory power is low. This may be because a lot of variables of as-built inspections were left out. On the other hand, $D - W = 1.456$, 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 design competence on the as-built inspection

was the largest ($\beta = .184$). The results of the significance test were as follows. First of all, the building permit approval that is a parameter has to have a significant effect on the as-built inspection to meet the 3-stage conditions and indicate the mediating effect. The results of the significance test were as follows. It was found that the building permit approval which was a parameter had a positive effect on the as-built inspection which was a dependent variable and a statistically effect ($t = 2.360$ and $p = .000$). This satisfied the 3-stage conditions. In the case of the design competence that was an independent variable meeting the first and second stages among other independent variables, the value was lower than the standardized beta (β) value of the second stage in both cases. Therefore, the mediating effect was found to exist. In other words, the design competence had a positive effect ($t = 3.145$ and $p = .000$), so it was confirmed that it had a partial mediating effect. The design competence was analyzed to have a significant effect on the as-built inspection when testing it in other ways ($\beta = 1.84$ and $p < .000$). The value was reduced to less than the standardized regression coefficient β of .255 which was presented in the first stage. The approval for building permit which was a parameter was verified to have a positive effect on the as-built inspection ($\beta = 1.34$ and $p < .000$). These results confirmed that design competence had a positive, direct and significant effect on the as-built inspection and that the design competence had an indirect effect as a parameter between the building permit approval and as-built inspection. In terms of the effect of the design competence on the as-built inspection, the direct effect is .184 and the indirect effect is .352 (.218 and .134). In addition, the total effect is .352. This effect shows not only that a building permit gets approved well but also that the quality of as-built inspections is improved when firefighting engineers design firefighting facilities in accordance with the national fire safety standards by using their excellent design

competence, in order to prevent inadequate preparation of design drawings and documents and avoid frequent design changes. This proved the third study question, "The approval for building permit will have a mediating effect on the firefighting engineer's design competence and the as-built inspection."

5.3.4 Final Consideration

In the first stage of the mediation effects of the building permit approval on the influence of apartment firefighting engineers' design competence on the as-built inspection, firefighting engineers' design competence was found to be an independent variable with the mediating effect on the building permit approval. The firefighting engineers' design competence was found to have a mediating effect on the building permit approval in relation to the as-built inspection of firefighting facility construction in the second and third stages. Also, the design competence was found to have a partial mediating effect.

5.3.5 Statistical Significance Test of Mediation Path

The test results of this mediation effect through the Sobel test (Mackinnon, Lockwood, Hoffman, West & Sheets, 2002) are shown in Table 5. The z value of the mediating effect which the building permit approval had on the relationship between firefighting engineers' design competence and as-built inspection is 7.13, which is statistically significant at the level of $p < .001$. (the mediating effect is significant when $|Z| > 1.96$). For this reason, the building permit approval has a partial mediating effect. This proved the third study question, "The approval for building permit will have a mediating effect on the firefighting engineer's design competence and the as-built inspection."

Table 5. Sobel Test to Verify Statistical Significance of Mediation Path

| Path between Variables | Z | p-value |
|--------------------------|------|---------|
| Design Competence | 7.13 | .000*** |
| Building Permit Approval | | |
| As-Built Inspection | | |

Conclusions

This study analyzed the effect of the apartment site firefighting engineers' design competence on the as-built inspection and the mediating effect of the building permit approval. The analysis results are as follows.

First, it was found that the design competence of firefighting engineers had a positive effect on the approval for the building permit. This implies that the better the firefighting engineers are to prepare design drawings to meet the national fire safety standards, the better the building permit is approved.

Second, it was found that the design competence of firefighting engineers had a positive effect on as-built inspections. It showed that poor design competence or poor design that did not take into consideration the site conditions led to poor completeness of design drawings and documents, thus affecting the quality of as-built inspections. In other words, the higher the completeness of the design drawings and documents prepared by the firefighting engineers is, the more positive its effect on the quality of the as-built inspections is.

Third, the approval for the building permit was found to have a mediating effect on firefighting engineers' design competence and as-built inspection. Building permit approval that was a parameter had a positive and statistically significant effect on the as-built inspection which was a dependent variable. This result means not only that a building permit gets approved well but also that the quality of as-built inspections is improved when firefighting engineers design firefighting facilities in accordance with the national fire safety standards by using their excellent design competence, in order to prevent inadequate preparation of design drawings and documents and avoid frequent design changes.

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