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What are the Risks of using Smart Technology in the Construction Phase?

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Abstract: In the era of the 4th Industrial Revolution, smart technology being considered to improve productivity breakthroughs is in the spotlight as a means to replace traditional construction technology in the construction industry. However, various problems are occurring in construction sites using smart technology and causing negative impacts on construction projects. Therefore, the objective of this study is to identify risk factors that occur when smart technologies are used in construction projects. To achieve this purpose, this study investigated the difficulties at construction projects using smart technology, and risk factors were derived based on site surveys and literature. The risk factors were measured by experts, and then a total of 19 risk factors was derived by exploratory factor analysis. As a result, risks were classified as 5 factors, the institutional factor is the most difficult response, and the government needs anticipative system improvement and a long-term plan. The research findings provide practical implications for construction experts trying to apply smart technology in construction sites and construction policy-makers to revitalize smart technology.

Key words: Construction 4.0, Smart Technology, Risk, Exploratory Factor Analysis

1. INTRODUCTION

The construction industry is almost the only industry whose productivity has declined over the past 50 years. In the case of the United States, productivity in areas other than construction and agriculture has increased by an annual average of 1.9% over the past 50 years, but the construction sector has been on the decline since the late 1960s [1]. However, in the era of the 4th Industrial Revolution, many industries are attempting digital transformation, especially the digital transformation of the construction industry is considered a technological innovation and is expected to solve the chronic productivity problem of the construction industry. This digital transformation of the construction industry is Construction 4.0 framework, and innovative advances of construction technology are occurring in this progress. Construction 4.0 is the 4th Industrial Revolution of the construction industry, which refers to a framework for combining new technologies with traditional construction technology or developing digital construction technologies to meet the purpose of the construction project [2]. In addition, various new technologies developed through the Construction 4.0 are smart technologies [3,4] and are expected to replace traditional technologies as newly advanced technology that is going to innovate the construction process [2].

However, in terms of time and space utilization, the ways of smart technology to apply to the construction process have very different from the existing traditional technology. These differences continue to occur while experts utilize smart technologies for the construction project and, appear in various areas such as institutions, technology, and finance. Moreover, it is becoming to causes construction risks which is able to happen difficulties in applying smart technologies. These risks also make construction firms evade application of smart technology because the uncertainty of risk get hinders project performance. Therefore, construction firms need to identify risks for the use of smart technology in advance and establish strategies for risk management. Thus, the purpose of this study is to investigate the possible risks when newly emerging smart technologies are applied in construction sites.

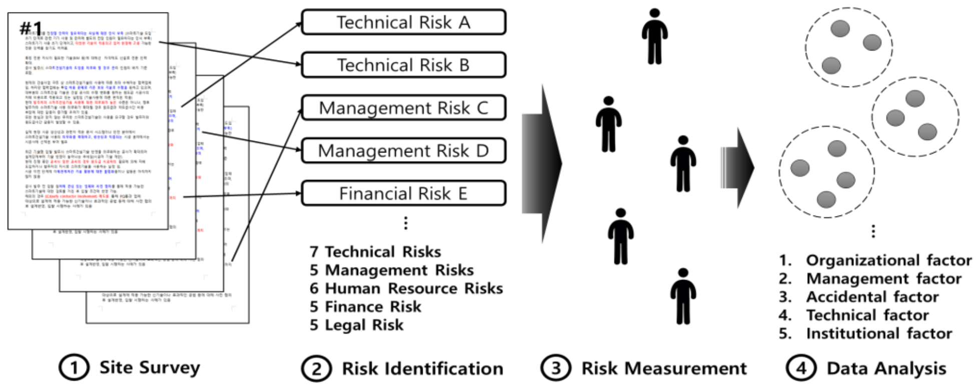

Figure 1. The Research Process

2. METHODOLOGY

2.1. Risk Identification

In order to identify the risks of using smart technology, 77 construction sites where smart technologies are used were investigated on difficulties and problems in detail when using technologies on the site. Risks were derived based on the investigation results. The risks duplicated contests were adjusted, and a total of 20 risks relating construction phase were derived. However, since the risks derived were based on the construction site, it is necessary to supplement areas other than construction phase. Therefore, the candidate risks were supplemented to cover broad categories through literature surveys related to the problems of these smart technologies. The problems of smart technologies in the literature mainly focus on the general events of initial technology phase such as device continuity, additional work, development cost, and institutions. To organize the risks systematically, risks were classified according to the nature of the risk and classified into five categories such as technical, management, human resource, finance, legal and administration. In addition, a total of 28 risks were finally derived by supplementing the level, terminology, and ambiguity of risks through the expert pilot test.

Table 1. Risks of Smart Technology in Contruction Industry

Classification	Code	Risks	Ref
Technical	T1	Difficulty in using many workers in VR/AR for construction site education	-
	T2	Design change due to errors of smart construction equipments	-
	T3	The lasts for a short time for portable battery-based smart devices	[2,5]
	T4	Technical difficulties due to field conditions such as weather and tunnel sites	-

	T5	Fatigue caused by additional work due to lack of connection among technologies	[5,6,7]
	T6	Uncertain reliability of analyzed results from using smart technology	-
	T7	Failure and malfunction of smart devices	-
Management	M1	Difficulties due to concerns about loss or damage of portable devices	-
	M2	Confusion arising from the lack of communication related to technology utilization among stakeholders in advance	[2,8]
	M3	Electronic documents sharing not widespread across players in the construction supply chain	[2,8]
	M4	Differences in conflicting technology utilization incentives or benefits among stakeholders	[2,8]
	M5	Limitation on the use of technology application caused by difficulties in collecting data due to regulations	[2,5]
Human Resource	H1	Refusal to use smart technology causing from the conventional work culture	-
	H2	Difficulties in timely technology application due to unfamiliarities such as lack of learning, experience, and skill	-
	H3	Differences in opinions between technicians on the results of smart technology analysis	-
	H4	Productivity degradation due to inexperience of drivers of smart equipments	[2]
	H5	Difficulties in using smart devices for elderly construction site worker	-
	H6	Lack of experts who can operate smart technology	-
Finance	F1	Excessive increasing costs due to the continuous installation of smart devices at linear sites	-
	F2	Unexpected cost incurred by installing auxiliary equipment for technology	-
	F3	Cost burden of employee training and recruitment for smart technology	[5,7,9]
	F4	Burdensome initial investment costs for smart technology utilization and development	[5,7,9]
	F5	Uncertainty profitability for smart technology utilization	[5,7,9]
Legal and Administration	L1	Difficulties in using the technology not in the specification	-
	L2	Confusion due to lack of technical guidelines and standards.	[2,7,9]
	L3	Confusion of stakeholders because of regulations not established related to smart technology	-
	L4	Limitation of utilization due to regulatory at interdiction and special zones such as military areas, etc.	-
	L5	Barriers to entry into the construction industry of related industries caused by differences in institution, ordering system	[2,5]

Note. Blank means the development of risk via construction site surveys.

2.2. Measurement and Survey

Many studies have been conducted on the probability and severity characteristics of risk, the probability refers to the probabilistic level at which risk can occur in projects, and the severity is an indicator of the negative impact of risk on projects [10-15]. The characteristic of risk complexity was added additionally to consider the independence of risk, time constraints, and degree of progress [16]. Risk complexity refer to the characteristics of risk linked levels or complex relationship in the system, which can indicate difficulties in responding to risks [16-18]. Considering the characteristic of complexity, it is able to establish multilateral strategies for risk response. Therefore, in this study, the characteristics of risk were measured by adding complexity to the existing probability and severity.

In order to measure the quantitative level of risk, a survey was conducted for a month on construction experts in Korea. The survey candidates are experts who are applying smart technology on their construction projects and, they are general or subcontractors. All characteristics of risks were measured according to a 5-point Likert scale. In particular, in order to minimize distortion of risk measurement, the background and purpose of this study were explained by contacting all respondents in person. It had been tried to contact a total of 282 candidates, 193 candidates were connected, and the distribution of the questionnaires was sent to candidates by e-mail. Finally, 105 candidates responded to the survey and the response rate of 54%. This response rate is higher than 20%, which can consider to be an appropriate rate for data analysis [19]. Specific information on the respondents is shown in Table 2.

Table 2. Survey Information

	Experience(years)				Contractors		Project Areas				
	<5	5～10	10～20	20<	Gen	Sub	Building	Infra	Mech	Elec	Tele
Ratio	12	28	46	14	57	43	31	51	9	3	6

	Applied Smart Technology									
	Automation	3D printing	Wireless network	Modular	AR/VR	AI	UAV	Big data	BIM	IoT
Ratio	13	1	10	12	7	7	15	6	16	13

Note. The unit of the ratio is percentage(%), Gen = General contractor; Sub = Sub-contractor; Infra = Infrastructure; Mech = Mechanical; Elec = Electric; Tele = Telecommunication

2.3. Data Analysis

In order to analyze the measured risks, characteristics were converted using a combination of the severity and probability of risks, which is widely used a technique in terms of engineering risk analysis [10,20]. This combination, probability combined with severity, has been conducted in various studies [10-15], and the combined risk factor is able to be considered the final level of risks. Also, box plot was used to compare the relative positions of the risk complexity. Box plot is valid method for intuitively understanding the distribution of data through median, mean, quartiles, and the lowest and highest data points [21]. Therefore, this method is easy to establish standards for interpreting the meaning of complexity of smart technology through distribution of complexity.

Smart technologies used in construction sites are not currently generalized technologies, and the risks that may arise when applying these technologies have not yet been theoretically established. Moreover, some of the risks identified were derived through literature, but most of them were derived from site surveys. Therefore, it needs to understand the potential risk characteristics and correlations. For these reasons, this study was conducted the exploratory factor analysis for deriving common factors and identifying structures of smart technology risks.

Communality was considered a ratio of factor explanation, the value is 0.4 or below was explained to have poor explanatory power [22], and the analysis was repeatedly conducted by removing the factors. If the KMO(Kaiser-Meyer-Olkin) measure of sampling adequacy value is close to 1, the variable setting is the more appropriate for this analysis [23]. For the extracted risks with a load value of 0.40 or less of the rotated component matrix were removed as it was considered that the correlation was poor [24]. In addition, for extracting one factor, it is meaningful to base at least three risks, so the risks that do not correspond to this were eliminated [22,25]. The variance ratio refers to the explanatory power of the factor, and the explained ratio should be higher than the ratio that was not described by the factor. Therefore, the rule of thumb factor has appropriate explanatory power if the total cumulative variance ratio is at least 50% or higher [24,26].

3. RESULTS

As a result of the exploratory factor analysis, 9 out of a total risks were excluded from the analysis by impeding validity, and a total of 19 risks were finally derived. The KMO indicator was used to measure the suitability for measurement variables, and Bartlett's Test of Sphericity was conducted to confirm the significance among risks. As a result of the analysis, the KMO value was 0.815 and Bartlett's test of sphericity was less than 0.05 of significance, so the factor analysis model was suitable. The cumulative variance was 65.69%, indicating that the explanatory power of the five factors is appropriate.

As a result of repeating the refining and analysis of the factors a couple of times, 19 risks were identified as five factors explaining 65.69% of the total variance. Based on the configured risks, the first factor was named organizational, the second factor was named management, the third factor was named accidental, the fourth factor was named technical, and the fifth factor was named institutional. All of the loading values of the factors were 0.4 or higher, satisfying the overall measured validity of the risk factors. In terms of risk complexity, it was analyzed as follows. The median was 3.157, the mean was 3.172, the upper quartiles 3.513, the lower quartiles 2.908, the lowest value 2.305, and the highest value 3.710.

Table 3. Rotated Component Matrix of Risks

Code	Risk Complexity	Communality	Risk Factors				
			F1	F2	F3	F4	F5
H1	3.397	0.604	0.765				
H2	3.115	0.533	0.707				
T5	3.618	0.421	0.607				
H6	3.107	0.414	0.566				
F5	3.708	0.441	0.565				
M3	2.893	0.807		0.880			
M4	3.531	0.531		0.668			
M2	3.351	0.418		0.626			
F2	3.183	0.754			0.833		
F1	2.954	0.705			0.732		
M1	2.305	0.485			0.612		
M5	3.138	0.401			0.508		
T2	3.069	0.476				0.682	
T7	2.809	0.449				0.628	
T6	3.308	0.530				0.603	
L2	3.626	0.733					0.846
L1	3.588	0.605					0.762
L3	3.569	0.442					0.628
L5	3.710	0.501					0.589
Eigenvalues			6.338	1.949	1.541	1.403	1.221
Variance explained(%)			33.360	10.418	8.111	7.383	6.428

Cumulative of VE(%)	33.360	43.778	51.889	59.271	65.699
Cronbach's α	0.786	0.756	0.780	0.665	0.795

Note. All loadings greater than 0.40 are shown. Complexity is calculated as an arithmetic mean. F1 = Organizational; F2 = Management; F3 = Accidental; F4 = Technical; F5 = Institutional.

4. DISCUSSION

The first factor is comprised of five risks and is named the organizational factor. This factor includes the organizational culture of conventionally handling tasks, the lack of capacity for smart technology, and the risk of uncertainty in profits. Thus, these risks show that the utilization of smart technology by construction firms is a burden from an organizational point of view. In particular, it has a very high complexity for construction firms to respond to the risks of connectivity or profitability between smart technologies existing. Therefore, construction firms need to establish strategies or plans in a long-term perspective for projects that utilize smart technologies.

The second factor is comprised of three risks and is named the management factor. This factor consists of the problems caused by arising among stakeholders, it shows that there is not enough understanding and agreement on smart technology. In addition, these risks tend to have high complexity, it is difficult to respond to risks through the efforts of individual firms. Therefore, it is necessary for smart technology to be generally distributed to the construction industry in advance. It suggests that it needs time to a consensus on smart technology for stakeholders in the construction industry.

The third factor is comprised of four risks and is named the accidental factor. This factor consists of unpredictable risks arising from the difference between smart technology and traditional technology operating processes in the construction phase. These risks are difficult to predict due to some obstacles such as experts' lack of experience in smart technologies, unaccustomed work. Furthermore, these obstacles could cause possibly occur accidentally during carrying out the projects. However, the complexity of risks was not high than comparing others. Thus, if firms are in a position to avoid risks, it implies that it is able to be replaced with existing technologies instead of using smart technologies in the same process.

The fourth factor is comprised of three risks and is named the technical factor. This factor consists of risks arising from technical limitations of smart technology. Since smart technologies distributed to the construction industry are still in their early stages, the technologies have to be improved through continuous feedback. In addition, the risks which the technology's own defect can be related to the low reliability of performance. The complexity of risks is not high and can be replaced with existing technologies. Therefore, technical factor implies the same lower burden on construction firms as the accidental factor.

The fifth factor is comprised of four risks and is named the institutional factor. This factor consists of risks arising from unrecognized regulations about the application of smart technologies in current construction system. The operational method of smart technology exceeds temporal and spatial limitations in a different way than traditional technologies. But, existing laws such as aviation, information, and others are being regulations to hinder using smart technologies because it is based on traditional technology processes. On another hand, owners are not approving the project performances generated from smart technologies because there are no reliability references. Furthermore, the institutional factor is the most higher than others in terms of complexity. All things considered, this factor is difficult for construction firms to respond to risks, and are the most problematic risks in the construction industry. Therefore, institutional improvement has to consider the most priority to revitalize smart technology, it suggests that the government needs anticipative system improvement and a long-term plan.

5. CONCLUSION

This study identifies the risks arising from the utilization of smart technologies in construction projects. For this purpose, is was investigated occurring problems due to using smart technologies at the construction sites, and risks were derived based on literature and field research. In order to analyze the risk characteristics and structure of smart technology, each indicator was measured by experts who are using smart technology on the construction site, and risk factors were derived through exploratory factor analysis.

This paper presents the following implications. First, organizational and management factors are difficult for firms to respond to individually, and construction firms need to establish response strategies in accordance with their risk attitude. Second, in the case of accidental and technical factors that can be replaced with existing technologies, the risk burden of firms is lower than other factors, but continuous technology improvement through feedback is needed for removing risks. Third, it is most difficult to respond to the institutional factor of smart technology, and preemptive institutional improvement is urgently needed to revitalize technology.

Overall, the results of this study contribute to providing references for responding to the prior risks of construction industry policymakers and experts using smart technology. But the researchers of this study recognize the limitations associated with specific risks interpretation in terms of practitional perspective. Thus, it will be conducted to research on how to resolve each risk based on these results of smart technology in the future.

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