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Estimating Risk Interdependency Ratio for Construction Projects: Using Risk Checklist in Pre-construction Phase

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Abstract Risk assessment during pre-construction phase is important due to the uncertainty of the risks that may exist in projects. Risk checklist is a method to systematically classify and organize the risks that have been experienced in the past, and to identify the risk factors that may be present in the future projects. In addition, risk value assessment based on checklists plays a key role in risk management, and various risk assessment researches have been conducted to carry out this systematically. However, previous approaches have limitations in common, this is because risk values are evaluated individually in risk checklists, which ignore interdependencies among risk factors and neglect the emergence of co-occurrence of risks. Hence, when multiple risk factors co-occur, they cannot be far off from the conventional method of summing the total risk value to establish the risk response strategy. Most of risk factors are interdependent and may have multiple effects if occurred than expected. In particular, specific cause can be overlapped if multiple risks co-occur, and this may result in overestimation of the risk response for the future project. Thus, the objective of this research is to propose a model to help decision makers to quantify the risk value reflecting the interdependency during the identification phase using existing risk checklist that is currently being practiced in actual construction projects. The proposed model will provide the guideline to support the prediction and identification of the interdependency of risks in practice. In addition, the better understanding and prediction of the exceeding risk response by co-occurring risks during the risk identification phase for decision makers.

Keywords: Risk Checklist, Risk Identification, Risk Co-occurrence, Risk Interdependency, Risk Value applied with Interdependency Ratio(RVIR)

1. INTRODUCTION

Construction projects are exposed to numerous risks, since all of projects are unique and have different uncertainties in each project (Mulcachy, 2003). Therefore, there is no such project that is considered as risk-free (Tüysüz et al., 2006). If risks are not properly managed in the construction project, the risk factors that threatens the construction cannot be identified, which increases the possibility of schedule delay and cost overrun that may lead to the failure of a project (Chapman, 2001). In order to prevent such situation, it is essential to perform risk management before each project is implemented.

Risk checklists are widely used in the construction industry during the risk identification phase in construction risk management. Risk checklist is a method to classify and organize the risks that have been experienced in the past, and to identify the risk factors that may be present in the future projects (Eybopoosh et al., 2011; Liu et al., 2013). Risk checklists are also used as a basis for risk value, which represents the magnitude of the risk that is measured (Kim, 2015), assessment at the risk identification phase, since risk checklists are relevant to risk planning and evaluation method that are regularly updated and verified to be applied to actual projects (see Figure 1).

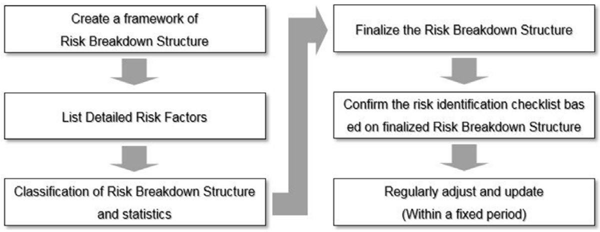

Figure 1. Procedures for creating the risk checklist during pre-construction phase

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Risk value assessment based on checklist plays a key role in risk management, and various assessment researches have been conducted to carry out this systematically. However, such researches have limitations in common. This is because risk values are evaluated individually in risk checklists, which ignore interdependencies between risk factors and neglect the emergence of co-occurrence of risks (Yildiz et al., 2014).

The existence of risk interdependency is well recognized by risk management researchers and practitioners, and there are various researches about risk dependences. However, most of existing researches have suggested causal model of risk factors to express dependencies between each risk that lacks the degree of the mutual impact of each risk factor, which is defined as dependency power (Iyer et al., 2010). These kinds of approaches may find out the cascading effect of risks, however, when multiple risks co-occur; existing models have limitation to use conventional method of summing the total risk value to establish the risk response strategy.

Most of risk factors are interdependent and may have multiple effects if occurred than expected. In particular, specific causes can be overlapped if multiple risks co-occur, and this may result in overestimation of the risk response for the future project (Yildiz et al., 2014). Overestimation of risk value during the risk identification phase leads to over-investment before the implementation of project, which increases the likelihood of cost-overrun and opportunity losses (Teller et al., 2013). Therefore, systematic management of the risks that may adversely affect the project in pre-construction phase is necessary (Kim et al., 2008).

The two most commonly used techniques to establish risk checklist are structured one-to-one interviews and brainstorming. While risk managers evaluate the risk value within the checklist, it becomes immense for the risk managers to trace the original causes of each risks (Iyer et al., 2010). In other words, instead of specializing in the foundation cause, they regularly tend to cease on assessing immediately preceding risks (Iyer et al., 2010). According to previous researches, the risks arising from inadequate design changes and construction method changes in domestic construction are considered to be more important relatively than other construction related risks (Lee et al., 2008; Hwang et al., 2008). This is because assessment of such risks requires on-site condition such as regional environment, weather condition, etc., which is difficult to judge precisely during risk identification process. (Yoo et al., 2006; Lee et al., 2008). For this reason, the design change and construction method change risks occur more frequently than other risks, and existence of overlapping relationship of causes is higher than other risks. However, since further breakdown of checklist during pre-construction phase is virtually impractical, an appropriate method to quantify interdependency reflected design change and construction method change risks using checklist is essential.

The objective of this research is to propose a model to quantify the risk interdependency within existing risk checklist that is currently being practiced in construction projects. The proposed model will provide the guideline to support decision makers to determine more optimized response strategies for the co-occurrence of multiple risks in practice.

The scope of this research is focused within the design change and construction method change risks in checklist. Since the characteristics of each construction project are unique, it cannot be assumed that the risk of design change and construction method change is the most frequent risk in all project. However, those risks are considered as included in most of construction projects; therefore, they are intended to be the main subject of this research. In addition, the risk value may be decreased or increased if interdependency is applied; thus, this research focuses on the part where risk reduces by overlapping relationship when interdependency of risks is reflected.

2. RISK MANAGEMENT PRACTICES

In order to develop a response strategy for each risk, the assessment of risks in risk identification phase is essential. When establishing the risk checklist, the risk value (RV) of each risk is measured as following:

$$RV = f(Probability, Impact) = P_i \times C_i \quad (2.1)$$

If such a risk factor occurs, the evaluated risk probability and impact are multiplied to determine whether it exceeds the risk tolerance level of the activity (Kim et al., 2010). This process helps decision makers to distinguish the level of risk. For example, high impact of risk does not always mean the level of risk is also high, if the probability of occurrence is negligible (see Table 1).

Table 1. Example of Risk Value Calculation (PMBOK, 2000)

C_i / P_i	Very Low 0.05	Low 0.1	Medium 0.2	High 0.4	Very High 0.8
0.9	0.045	0.090	0.180	0.360	0.720
0.7	0.035	0.070	0.140	0.280	0.560
0.5	0.025	0.050	0.100	0.200	0.400
0.3	0.015	0.030	0.060	0.120	0.240
0.1	0.005	0.010	0.020	0.040	0.080

Since the risk values are calculated independently for each risk factor, the countermeasures are also established independently. For example, if there are a total of 20 risk factors, the 20 different risk values will be measured and summed up followed by the risk response strategy, which will also be equally summed up (see Table 2).

Table 2. Simple Tabular Calculation of Estimating Contingency (Wideman et al., 1992)

Description of Risk Factor	Probability of Occurrence (%)	Estimated Cost of Consequences ($)	Risk Value ($)
Risk A	Probability *Pi*	Impact ($) *Ci*	RV $= f(P_i \times C_i)$
Risk B	…	…	…
Risk C	…	…	…
…	…	…	…
Project Estimating Contingency based on:			$\sum P_i \times C_i$

A clear criterion should be established to assess the level of risk to determine the risk response strategy, which is defined as the risk threshold (RT). Risk threshold is based on comprehensive consideration of the management environment, organization, scale and form of project, and other external environment of the construction company concerned. Based on risk threshold, it is able to determine whether to establish a risk response strategy for each risk. If risk values are summed up from the existing risk checklist, it can be decided whether the risk tolerance is exceeded or not. In other words, if the total of risk value falls below the risk threshold level, the project managers continue with the project at risk. This process can conserve time and cost in construction.

However, applying risk interdependency can result in a change compared to the sum of previously measured risk value due to sequential or cyclical nature of interdependences. Thus, the risk response strategy should be established differently due to the interdependency between risks. If the risk factors are interdependent, the outcome of risk value will vary and be more efficient to establish optimized risk response strategy. Since evaluated risks in checklist are identified and managed independently, project managers often discount the interdependency relationship of risk factors while formulating risk response strategy. This is because it is difficult to recognize the complex interactions of impact that occur among the risks (Iyer et al., 2010). Practitioners defined risk dependency as an effect that can increase the probability of occurrence by cascading relationship of risks (Kwan et al., 20100 and Cavallo et al., 2014). In spite of that, this research focuses on overlapping relationship of risk causes to reduce the risk value rather than cascading effect.

The opinions investigated from the structured interviews with the 11 risk management experts concluded that the risk would reduce if risk interdependency were reflected. Most common reason for the decrease in risk value is that considering interdependency of risks is the evidence of better understanding and predicting the solution of risks, which will decrease the probability and impact of each risk. On account of the basic concept of risk management, which is a process for making better decisions under conditions of uncertainty remains (Nigel et al., 1996; Mulcachy, 2003), it is important to reduce the risks with better perception to decrease the overall cost of construction.

3. PREVIOUS RESEARCHES ON RISK DEPENDENCY RELATIONSHIPS

In accordance with risk interdependency, there are notable researches that have conducted such subject. Leu et al. (2003) have suggested the Bayesian-network based risk assessment model for steel construction projects. The suggested model provides the competence to calculate the risk probability based on their relationships in Bayesian-network. Fu et al. (2012) has conducted research about change in risk assessment method with impact propagation based on Dependency Structure Matrix. The proposed model supports the prediction of change propagation of risks by establishing dependency relationship to avoid unnecessary re-designs. Yildiz et al. (2013) proposed a knowledge-based risk-mapping tool for the assessment of risk that may lead to the cost overrun of international construction project. This tool allows risk managers to refer the risk histories and interrelationship of previous projects in order to estimate risks for future projects. Iyer et al. (2010) suggested hierarchical structure analysis of public-private partnership risks based on interpretative structure modeling. Hierarchical structure provides the interrelationships among risk factors to enable decision makers to assess risk in appropriate way. Kwan et al. (2010) proposed methods to estimate the impact of risk by utilizing the dependency effect, and establishing risk response strategies based on the developed risk dependency relationship. Eybopoosh et al., (2011) conducted research about developing the causal relationships among risk factors in order to determine the risk paths using structural equation modeling; this research considers the identification of a network of interactive risk paths. Cavallo et al. (2010) suggested a model of risk interdependency for disaster prevention strategies by networking approach. This approach addresses complex interdependent risk for unforeseen which may chain occur. Teller et al. (2013) provided the evidences that new methodologies addressing the interaction of risks should be developed for the transparency of risk management. The previous literatures mentioned above have made considerable contributions to risk assessment analysis. However, these approaches have similar limitations from quantitative and on-site workers' perspectives. Since these approaches are based on network relationship of risks, most of the researches have adopted the causal model to establish the dependency relationship of risks using binary format. These types of approaches may neglect the change in impact of risk because such format is not able to consider the quantitative aspect of estimating interdependency between risks that may affect the risk value.

4. METHODOLOGY FOR MEASURING RISK INTERDEPENDENCY

Apart from the construction industry, method such as

'Interregional Input-Output Mode' is applied to measure the interdependency ratio of each factors in economics (Oosterhaven et al., 2014). In interregional input-output model, the power of backward dependency and the forward dependency of an industry are measured in order to estimate the interdependency ratio between industries. The backward dependency of the industry is the degree to which intermediate goods are purchased from other regions for the production activities, and the degree to which finished products are sold as intermediate goods in other region is defined as forward dependency (Lee et al., 2006; Yoon et al., 2010).

Figure 2. Forward and backward dependency relationship

In order to establish risk interdependency relationship, it is necessary to distinguish the direction of dependency power. For instance, if R_a receives influence and R_c gives influence to R_b, then R_b has forward dependency to R_a and backward dependency to R_c. At a given time, if risk impact is estimated appropriately, the foundation causes of R_b can be assumed to overlap with the causes of R_a and R_c. In addition, if Rb were judged to have no forward or backward dependencies to other risks, it can be evaluated independently. Thus, in order to determine the amount of each risk effecting other factors, this research focuses on deriving the grade or number of the interdependence of the risks by evaluating the forward dependency power through expert's interview and measuring the backward dependency to establish the interdependency ratio.

The Reachability matrix is considered to be the most suitable representation method of the risk interdependency relationship, since it is a method of illustrating the effects of a set of items in a series (Iyer et al., 2010). This can be viewed as a visual representation of the interdependency among risk factors. Thus, interdependency relationships of risks are proposed in such matrix format for this research (see Table 3).

In this Table 3, the interdependency among risk factors is expressed on a 5-point scale, where the risk factors of the forward dependency axis affect the risk factors of the backward dependency axis. For instance, if the 'Risk D' in the forward dependency axis is evaluated to have dependency power of '4' on the 'Risk A' on the backward dependency axis, the 'Risk A' on the backward dependency axis is judged to have a strong dependence on 'Risk D'.

In order to evaluate the ratio of dependency power, methods are tested to validate their feasibility for deriving the result value of this research. To elucidate the most feasible method for measuring Interdependency Ratio (IR) based on risk interdependency matrix, several methods that previous researches have conducted such as Dependency Structure Method (DSM), Influence Diagramming, Concept of Interdependency within an Organization, Interpretative

Table 3. Example of risk interdependency matrix

Risk Factors		Backward Dependency					
		Risk A	Risk B	Risk C	Risk D	Risk E	Risk F
Forward Dependency	Risk A		0	0	0	0	0
	Risk B	0		0	0	0	0
	Risk C	4	0		1	2	5
	Risk D	4	3	0		2	0
	Risk E	1	0	0	0		0
	Risk F	1	1	0	0	0	

Table 4. Review of methods for measuring interdependency ratio

Methods for measuring Interdependency Ratio		Reviewed Items			
		Dependency Representation	Quantification	Multiple Factors	Interdependency Ratio
1	Dependency Structure Method	✓		✓	
2	Influence Diagramming	✓	✓	✓	
3	Concept of Interdependency within an Organization	✓	✓		✓
4	Interpretative Structural Modeling	✓		✓	
5	Structural Equation Modeling	✓	✓	✓	
6	Interregional Input-Output Model		✓	✓	✓

Structural Modeling (ISM), Structural Equation Modeling (SEM), and Interregional Input-Output Model (IRIO) are reviewed (see Table 4).

According to the result of review in Table 4, Dependency Structure Matrix and Interpretative Structural Modeling have feasibility to represent the dependency relationship. However, it is difficult to quantify the dependency power among risk factors since both methods are based on binary format, which is used for establishing the level of relationship between factors in hierarchical form (Iyer et al., 2010). In contrast, Influence Diagramming and Structural Equation Modeling provides quantification of dependency power. Nonetheless, the feasibility to analyze the measurement of interdependency ratio are ineligible.

As a result of the review, the Concept of Interdependency within an Organization and the Interregional Input-Output model, which is a method used in other industries than the construction industry, are able to analyze both relationship and dependency power between factors. However, the Concept of Interdependency within an Organization method have limitations in that the more the number of factors, the more difficult it is to measure them. Interregional Input-Output model is able to measure dependency power between industries in large scale; however, this model also has limitations in that it is difficult to measure the influence of each factor on the extent of the derived interdependence.

Therefore, in this research, concept of interdependency within an organization and the interregional input-output model will be modified as appropriate method of measuring Interdependency Ratio among Risk Factors. The validity of proposed model will be confirmed by measuring the Risk value applied with Interdependency Ratio using dependency value evaluated by structured interviews of experts.

Hong (1995) proposed a Concept of Interdependency within an Organization model, which is used to measure the interdependency ratio between the factors in particular division. With this method, the degree of dependence power of two divisions is constructed by using a matrix. The model is represented on Eq. (3.1) as follows,

$$\begin{matrix} Interdependency\ ratio \\ of\ division\ k \end{matrix} = \frac{\sum a_{kj} + \sum a_{ik}}{2(\sum\sum a_{ij})} \tag{3.1}$$

whereas a_{ij} refers to the value of the exchange where each row and column in the matrix-type relationship data intersect, and $\sum a_{kj}$ and $\sum a_{kj}$ refers to the degree of dependency power of division k on the other division. Lastly, $\sum\sum a_{ij}$ refers to the sum of degrees of dependence of the entire network within the matrix.

This model can be used to compare forward-to-backward dependencies simultaneously between the two divisions. However, since this research considers the numerous risk factors instead of limited number of factors, the model has to be modified in order to calculate the interdependency ratio, which can be defined as follows,

$$A = \frac{Total\ of\ Evaluated\ IR}{Number\ of\ Risk\ Factors \times Maximum\ IR} \tag{3.2}$$

whereas $Total\ of\ Evaluated\ IR$ refers to the sum of the evaluated dependency power by experts and $Number\ of\ Risk\ Factors$ refers to the number of risk factors that are influencing the selected risk factor that is measured at a time.

In the Interregional Input-Output Model, an initial value 'X' of specific division is sum of intermediate value 'Z' and final value 'Y' (Yoon et al., 2010; Oosterhaven et al., 2014). The basic structure of the formula is as follows

$$X = Z + Y,$$

$$X = \begin{bmatrix} X^L \\ X^M \end{bmatrix},\ Z = \begin{bmatrix} Z^{LL} & Z^{LM} \\ Z^{ML} & Z^{MM} \end{bmatrix},\ Y = \begin{bmatrix} Y^L \\ Y^M \end{bmatrix} \tag{3.3}$$

In the formula, variable 'Z' can be referred as the input ratio 'A' (0≤A≤1) of the intermediate value to the total output of the relevant parts 'X' (Lee et al., 1998 and Oosterhaven et al., 2014). Therefore, the formula can be relocated as follows.

$$X = AX + Y \tag{3.4}$$

For the purpose of calculating final value 'Y', the relocated formula must be modified as follows (Lee et al., 2006; Trinh et al., 2008).

$$X = AX + Y \rightarrow Y = X - AX \rightarrow Y = X(1 - A) \tag{3.5}$$

In Eq. (3.5), it can be verified that the final value Y of a specific input with interregional interdependence between divisions is deducted by a factor of interdependency ratio (A, 0≤A≤1) which is the input as intermediate value of initial value X. In other words, the larger the interdependence ratio inserted into the intermediate value, the smaller the scale of the final value. This is found to be similar logic of measuring the Residual Risk Value (RRV) in risk management.

In the risk management, the residual risk is defined as the remaining risk that is not completely removed after the execution of the countermeasure strategy, and the residual risk is represented as the numerical value of the Residual Risk Value (Grey et al., 1995).

$$RRV = RV(1 - ME) \tag{3.6}$$

In Eq. (3.6), Mitigation Efficiency (ME), which is the efficiency of the strategy that is, predicted when a risk response strategy is implemented (PMI, 2000). Thus, the greater the efficiency of the response strategy, the lower the residual risk from the existing risk. Since the logic of ME (0≤ME≤1) in Eq. (3.6) is similar to A (0≤A≤1) in Eq. (3.5), it can be replaced with 'A'

In this research, the risk interdependency should be deducted from the initial risk value (Initial RV) of the specific risk factor by the ratio that affects the other risk factors. Therefore, the draft formula for calculating the Risk Value applied with Interdependency Ratio (RVIR) by changing the mitigation efficiency (ME) to the interdependency ratio 'A' in the Residual Risk Value formula is as follows.

$$\begin{matrix} Y = X(1-A) \\ RRV = RV(1-ME) \end{matrix} \rightarrow RVIR = Initial\ RV(1-A) \qquad (3.7)$$

Finally, substituting 'A' from the RVIR draft formula to interdependency ratio of numerous risk factors formula, Eq. (3.2), finalizes the model that calculates the Risk value applied with Interdependency Ratio (RVIR).

$$RVIR = Initial\ RV\left(1 - \frac{Total\ of\ Evaluated\ IR}{Number\ of\ Risk\ Factors * Maximum\ IR}\right) \qquad (3.8)$$

RVIR = Risk Value applied with Interdependency Ratio
Initial RV = Risk Value that has calculated initially
IR = Interdependency Ratio

5. APPLICATIONS OF RISK INTERDEPENDENCY IN CHECKLIST

In this section, developed model from previous section is applied to risk interdependency matrix. The variables for the risk factor are selected from the risk checklist from 'L' Construction Company that is currently used in actual construction projects (see Table 5). There is a total of 15 risk in the checklist that is conducted for the research, 9 for design change risk and 6 for construction method change risk. The listed risk factors are considered to be the core factor of specific risks in checklist. From this list, other specific risks are branched out to be assess in the activities when the project is implemented.

Table 5. Design change and construction method Change risk classification in checklist of 'L' Construction Company

Major Class.	Minor Class.	Detailed Class.
Design Change Risks (Type A)	A-1	Discrepancies of site conditions and design
	A-2	Design Error
	A-3	Excessive Design
	A-4	Inaccurate Specification
	A-5	Inadequate Design Criteria
	A-6	Delayed Approval of Design Change
	A-7	Unclear responsibilities for design changes
	A-8	Insufficient design change budget
	A-9	Optimized cost calculation error
Construction Method Change Risks (Type B)	B-1	Inappropriate construction method selection
	B-2	Uncertainty due to special method
	B-3	Lack of feasibility review of public works
	B-4	Lack of experience in applying tech.
	B-5	Failure of new technology prediction
	B-6	Increased construction complexity

In order to prepare for measuring Interdependency Ratio among risk factors, the weights of dependency power for each risk factor are evaluated from structured interview of experts. The structured interview was performed with total of 11 experts. In order to evaluate the dependency power of each risk,

Table 6. Interdependency Matrix for Design Change Risks

Design Change Risks (Type A)		Backward Dependency								
		A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9
Forward Dependency	A-1		3.50	2.11	1.56	1.67	1.83	1.61	1.67	1.22
	A-2	1.67		2.39	2.22	1.72	2.11	1.83	1.56	1.50
	A-3	1.00	2.28		1.89	1.56	1.89	1.78	1.67	1.67
	A-4	1.72	3.56	2.28		1.83	1.83	2.00	1.56	1.50
	A-5	1.22	3.44	2.78	2.39		1.94	2.11	1.56	1.50
	A-6	0.50	0.67	1.06	1.33	1.22		1.50	1.67	1.11
	A-7	0.78	1.33	1.00	1.78	2.22	2.33		1.67	1.22
	A-8	0.67	0.89	1.17	1.33	1.67	3.44	2.13		1.89
	A-9	0.44	1.67	1.00	1.33	1.22	2.83	2.44	2.56	

Table 7. Interdependency Matrix for Construction Method Change Risks

Construction Method Change Risks (Type B)		Backward Dependency					
		B-1	B-2	B-3	B-4	B-5	B-6
Forward Dependency	B-1		2.33	2.83	2.33	2.22	3.11
	B-2	3.06		2.67	2.39	2.28	2.00
	B-3	4.11	2.56		2.78	2.11	2.33
	B-4	3.78	2.33	3.44		2.61	2.28
	B-5	1.72	1.94	2.56	2.11		1.28
	B-6	2.44	2.22	3.06	2.00	1.39	

the five selection criteria were established, which are: (1) Over 10 years of career in construction industry, (2) position is higher than General Manager in CM, (3) must have full understanding of each risk that are listed above, (4) numerous field experience, and (5) currently employed in the construction industry. Since risk management is a research that has subjective aspect, the selection criteria was formed particularly to obtain the most precise result.

In addition, since established selection criteria is rigorous, the number of experts to be interviewed were limited. The dependency power among risk value within the matrix is evaluated by the structured interviews with experts on a 5-point scale. Each of evaluated weight on the matrix indicates both forward dependency and backward dependency power of each risk (see Table 6 and Table 7).

Since the risk value may vary depends on the characteristics of the project, this research proposed the result if interdependency ratio measurement for each risk only. Nevertheless, the result of interdependency ratio can be adopted to risk checklist once risk value is estimated for the project. Thus, the results were derived with two assumptions, which are: (1) if the risk value of each risk is fixed at 100, and (2) all of risks have co-occurred simultaneously.

6. RESULTS AND DISCUSSIONS

The interdependency ratio calculation result has shown that design change risks has average of 30.91% interdependency ratio (see Figure 3) and method change risks has average of 41.25% interdependency ratio (see Figure 4).

The results show relatively high interdependency ratio, because the calculation is based on co-occurrence of all risks. For example, if only A-1 occurs during the project, A-1 should not consider interdependency since there are no other risks that have occurred to affect A-1. Therefore, risk value estimated previously remains constant. In case of co-occurrence between A-1 and A-2, the analysis shows the average of 5.74% of interdependency ratio between two out of nine risks for Type A, which means risk values do not change drastically. Other case, such as co-occurrence between B-1 and B-3, the analysis presents the average of 11.57% of interdependency ratio between two, out of six risks for Type B. This can be presumed as they have more detailed cause of risk are overlapping. In summary, decision makers can examine the change in risk interdependency by certain risks that they assume to co-occur.

In risk response perspective, the result of interdependency

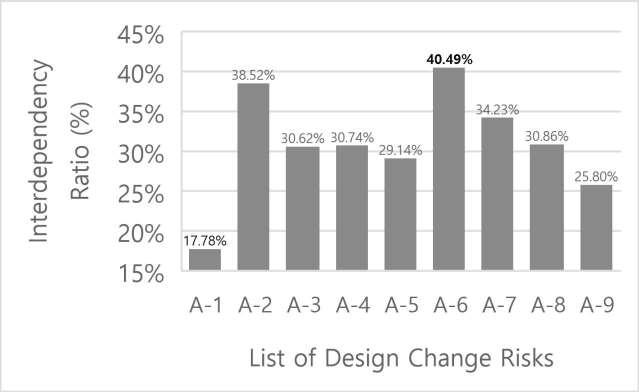

Figure 3. Interdependency Ratio of Design Change Risks

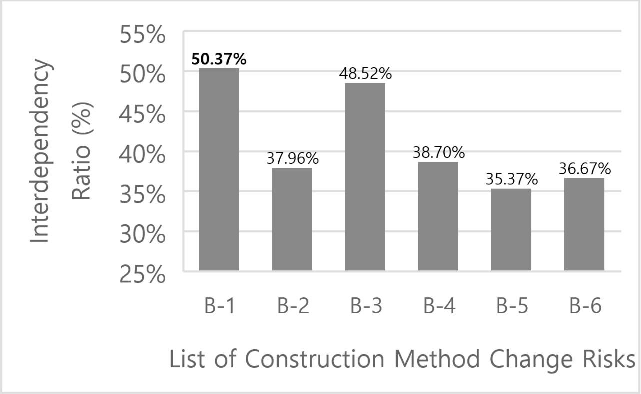

Figure 4. Interdependency Ratio of Construction Method Change Risks

ratio calculation can be the indication to overlapping relationship of response strategy. For instance, of present result, A-6 (Delayed approval of design change) risk has shown the highest interdependency ratio of 40.49% in design change risks and B-1 (Inappropriate construction method selection) for 50.37%. This kind of high ratio refers to that if other risks within the classification is responded; the risk can be mitigated to a certain degree. Although the remaining risk value cannot be neglected, it is appropriate indication to compress response strategy on such risks. In contrary situation, such as the least amount of interdependency ratio of 17.78% for A-1 (Discrepancies of site conditions and design), it can be considered to be the most independent risk that does not affect to other risks much. Thus, such risks are necessary to be managed separately, which also mean as respective establishment of response strategy.

The result may not determine the exact level of risks. Nonetheless, the result of interdependency ratio can be referred during the decision-making process during pre-construction phase. Nevertheless, this process can help decision makers to understand the interdependency relationship among selected risk factors under conditions of uncertainty remains.

7. CONCLUSIONS

Construction projects always contain a certain degree of uncertainties. To mitigate the risks in projects, checklist method is used to identify the risks during the pre-construction phase. However, current risk checklists have limitation that identified risks were evaluated individually, which neglects the influence of interdependency and co-occurrence. Thus, the approaches were made to support the assessment process of reflecting the dependency relationship of risks.

The existing methods can be used to distinguish the dependency relationship between each risk factors with causal model or binary format. However, the proposed model in this research has several advantages compared to other models. First, suggested method has specialty on deriving interdependency ratio of each risks. This is because it is important in risk management to presume the multiple effects that co-occurring risks can damage the project overall. Since existing models conducts the risk paths regarding cascading effects, it is difficult to detect the overlapping relationship for causes of occurrence. Secondly, the improvements on existing checklists were expected to made depends on the characteristics of company. Since risk checklist is updated by past data from previous projects, the decision makers can weigh dependency power on each factor differently each time. In addition, calculated interdependency ratio by proposed model grants guideline for decision makers to set the risk response priority. For example, the risk with highest interdependency ratio in specific breakdown structure indicates that if other risks that affects the risk are managed, it can be responded simultaneously to a degree. In contrast, the risk with least amount of interdependency ratio indicates that it does not interact with other risks; therefore, decision makers can recognize that it is needed to be managed or responded independently than other risks.

The proposed model is competent to find the overlapping impact of multiple risks; therefore, it can help decision makers to establish risk response strategy with better understanding of co-occurring risks. For instance, decision makers can combine multiple strategies, which was individually evaluated, to single strategy to respond multiple risks concurrently.

The implication of proposed model is that project managers should acknowledge the importance of risk interdependency and co-occurrence. The inadequate consideration of risk co-occurrence or oversighting risk interdependency would cause an increase in budget during pre-construction phase, therefore adversely affects the overall benefits of the project.

This research limited the scope within design change and construction method change risks in checklist, the future researches will have to expand the scope of research by analyzing interdependency ratio of other risk factors in a construction project. However, since the environment and characteristics of construction project is diverse and complicated it may be virtually impossible to analyze the interdependency ratio of all potential risks in the construction project. Yet, the research will develop the scope of risks that are frequently encountered in construction projects or the major risk factors of a specific project in the future. Lastly, the present research only conducted the cases where the risk decreases due to the effect of interdependency; thus, future research will also should include the case of increase in risk by the degree of interdependency.

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