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Optimizing construction project completion: A risk-based approach

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ABSTRACT

A construction company has a significant issue within the project planning division in determining which construction projects to undertake, as the company only assesses them based on feasibility studies and overall project risks. To support the decision-making process in selecting construction project resolutions, research was conducted to propose selections based on risk criteria. This research aims to establish the risk criteria used, determine the ratings of risk criteria and sub-criteria, and identify project alternatives with the lowest risk ratings. From the data processing results, the risk criteria utilized are contractor risk, financial risk, environmental and natural risk, quality risk, and material risk. Using the Analytical Hierarchy Process manual method and Expert Choice 11 software, the ratings for contractor risk are 46%, financial risk 16.2%, environmental & natural risk 5%, quality risk 22.8%, and material risk 10.1%. Sub-criteria risk ratings are as follows: experience 15.2%, performance 30.8%, project funds 13.1%, budget increase 3.1%, social disturbances 3.5%, natural events 1.5%, material quality 8%, design quality 7.5%, building quality 7.2%, material delay 5.9%, and material specification 4.1%. The construction project alternative with the lowest risk rating is the guest house construction project at 0.132. Therefore, the guest house construction project is proposed for immediate prioritized completion.

1. Introduction

A construction company faces problems in its operation. In the construction process of these properties, a construction division is needed to serve as a planner for determining which property projects will be constructed. This division, known as the Business Development Directorate, needs to assess the feasibility of construction projects and decide which ones should be built immediately.

Currently, the Business Development Directorate is conducting feasibility studies on each project to determine which projects will be constructed immediately [1]. If the feasibility analysis shows that a project is viable, then the project can proceed. However, when it comes to risk assessment, the company only considers overall risk by assuming that all construction projects have the same level of risk. The inherent risk of each construction project cannot be equated because they vary depending on the type of construction [2]. Determining the risk value for a construction project requires identifying the possible risk criteria [3], [4].

Based on the possible risks in construction projects [5], a decision-making process is required to select projects that are feasible considering both feasibility studies and project risk values. Decision-making is a crucial step. Decisions made should be carefully considered and have a clear foundation [6].

In this study, the researcher aims to discuss the decision-making process to determine which project should be completed first at PT XYZ based on the existing risk criteria. The risk criteria used include contractor, financial, environmental, natural, quality, and material risk [7], [8]. The construction projects to be examined are the warehouse construction project, the MES construction project, the guest house construction project, and the water slide construction project. To determine the decision-making process for prioritizing project completion based on risk ratings, a method to calculate risk ratings is needed [9].

The Analytical Hierarchy Process (AHP) method is one of the techniques that can be employed to calculate risk ratings for decision-making [10], [11] in determining which project should be prioritized for completion first [12]. This method establishes a hierarchy of desired objectives in decision-making [13]. This research involves several experts who possess knowledge, experience, and perceptions relevant to making decisions regarding project completion selection [14]. The aims of this research are to determine the risk criteria used, establish the ratings of risk criteria and sub-criteria, and identify project alternatives with

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the lowest risk ratings, which are then proposed for the selection of construction project completions.

2. Material and method

In this study, field research is conducted to identify existing issues within the company, enabling improvements to be suggested regarding these issues. Subsequently, a literature review is conducted to gather various reference data related to the issues to be investigated. Problem formulation, research objectives determination, and setting the research scope are then undertaken to ensure the problems are more focused on resolution. In the next stage, initial data collection, which consists of general company data and realization of the project development process flow at PT XYZ, and data on construction projects, were obtained from interviews with company representatives. Data is then processed by identifying the risk criteria for proposing construction project selections [15], [16]. Subsequently, hierarchy structure development is performed, followed by creating a paired comparison questionnaire [17].

Table 1.
Pairwise comparison rating scale

Level of Importance	Definition	Explanation
1	Both elements are equally important	Both elements have equal influence.
3	One element is slightly more important than the other	Experience and assessment slightly support one element over the other.
5	One element is significantly more important than the other	Experience and assessment strongly support one element over the other.
7	One element is considerably more important than the other	One element is strongly supported and dominates in practice.
9	One element is more important than the other	The evidence supporting one element over the other has the highest level of affirmation possible.
2,4,6,8	Intermediate values between two adjacent comparison values	This value is given when there are compromises between two choices.
Inverse aij = 1/aij	If activity I receives a score of one when compared to activity J, then J has the opposite score when compared to I.	

Table 1.
The Random Index (RI) number

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

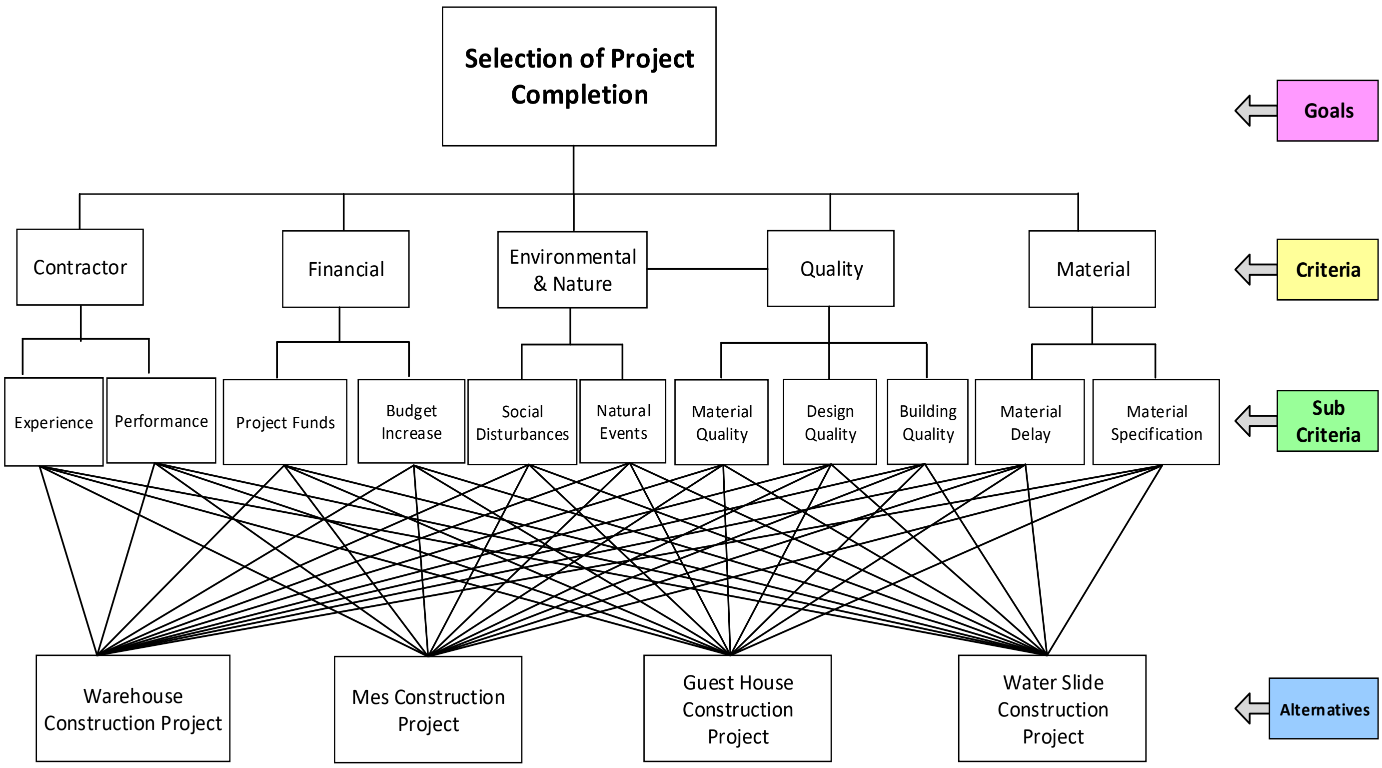


Figure 1. Hierarchical sructure

Table 3.
Geometric mean between risk criteria for project completion selection

Criteria	Respondents			Criteria	GM
	1	2	3		
Contractor	8	7	5	Financial	6.542
Contractor	9	7	5	Environmental & Nature	6.804
Contractor	0.167	5	5	Quality	1.609
Contractor	5	3	5	Material	4.217
Financial	7	5	5	Environmental & Nature	5.593
Financial	6	1	0.167	Quality	1
Financial	0.2	1	6	Material	1.063
Environmental & Nature	0.143	1	0.167	Quality	0.288
Environmental & Nature	0.125	3	0.2	Material	0.422
Quality	7	1	5	Material	3.271

Table 2.
Geometric mean between sub-criteria of risk regarding contractor risk criteria

Sub Criteria	Respondents			Sub Criteria	GM
	1	2	3		
Experience	0.167	0.143	5	Performance	0.492

Table 5.
Geometric mean between alternatives regarding the sub-criteria of experience risk

Alternatives	Respondents			Alternatives	GM
	1	2	3		
Warehouse Construction Project	6	0.333	0.167	Mes Construction Project	0.693
Warehouse Construction Project	6	0.333	6	Guest House Construction Project	2.289
Warehouse Construction Project	5	0.333	5	Water Slide Construction Project	2.027
Mes Construction Project	6	3	5	Guest House Construction Project	4.481
Mes Construction Project	0.25	0.333	5	Water Slide Construction Project	0.747
Guest House Construction Project	0.25	0.333	0.167	Water Slide Construction Project	0.24

In the second data collection phase, questionnaires are distributed to respondents who are experts familiar with construction projects. Three respondents assess the paired comparisons: the Sub Directorate of Development and Planning, the Division of Business Development and Risk Management, and the Division of Technical Planning. Fig. 1 shows the hierarchical structure of the mentioned problem. The rating scale used in the Analytical Hierarchy Process method [18], [19] can be seen in Table 1. The next stage is the second data processing, which involves analyzing the experts' questionnaire data. The data processing utilizes the Analytical Hierarchy Process method manually and will be subsequently verified using Expert Choice 11 software. Before calculating the pairwise matrices, the geometric mean will be calculated to obtain a single value from the combination of assessments from the three respondents. Eq. (1) shows the formula to calculate the geometric mean, where GM denotes the geometric mean, x_i is the average value scale 1-9, and n is the number of respondents.

$$GM = \prod_{i=1}^{n} x_i = \sqrt[n]{x_1 x_2 \dots x_n} \quad (1)$$

After calculating the geometric mean, the next step is to compute the priorities from the pairwise comparison matrix and perform consistency testing using Eq. (2),

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \quad (2)$$

where CI denotes the consistency index, λ_{max} is maximum eigenvalue of the matrix of order and n denotes the matrix order. The pairwise comparison matrix is consistent if CI is zero (0). The inconsistency threshold established by Thomas L. Saaty [20] is determined using the Consistency Ratio (CR), which is the ratio of the Consistency Index (CI) to the Random Index (RI), as shown in Table 2. The Consistency Ratio can be formulated as expressed in Eq. (3).

$$CR = \frac{CI}{RI} \quad (3)$$

If the pairwise comparison matrix has a Consistency Ratio (CR) value less than 0.100, then the inconsistency in the decision maker's opinions can still be acceptable. Otherwise, the assessments need to be reconsidered. After calculating the priorities of criteria, sub-criteria, and alternatives, the next step is to compute the global priorities, which are the priorities of attributes relative to the goals to be achieved. The manual calculation of the AHP method is completed, and verification is then performed using Expert Choice 11 software.

Table 6.
Pairwise comparison matrix between risk criteria

Criteria	Contractor	Financial	Environmental & Nature	Quality	Material
Contractor	1	6.542	6.804	1.609	4.217
Financial	0.153	1	5.593	1	1.063
Environmental & Nature	0.147	0.179	1	0.288	0.422
Quality	0.621	1	3.476	1	3.271
Material	0.237	0.941	2.371	0.306	1
Total	2.158	9.662	19.245	4.203	9.973

Table 3.
Pairwise comparison matrix between sub-criteria of risk and contractor risk criteria

Sub Criteria	Experience	Performance
Experience	1.000	0.492
Performance	2.033	1.000
Total	3.033	1.492

Table 8.
Pairwise comparison matrix between alternatives regarding the sub-criteria of experience risk

Alternatives	Warehouse Project	Mes Project	Guest House Project	Water Slide Project
Warehouse Project	1.000	0.693	2.289	2.027
Mes Project	1.442	1.000	4.481	0.747
Guest House Project	0.437	0.223	1.000	0.240
Water Slide Project	0.493	1.339	4.160	1.000
Total	3.372	3.255	11.931	4.015

Table 9.
Priority matrix between risk criteria

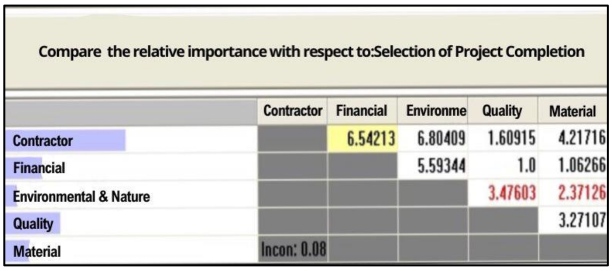
Criteria	Contractor	Financial	Environmental & Nature	Quality	Material	Ttoal	Priority
Contractor	0.463	0.677	0.354	0.383	0.423	2.3	0.46
Financial	0.071	0.103	0.291	0.238	0.107	0.809	0.162
Environmetal & Nature	0.068	0.019	0.052	0.068	0.042	0.249	0.05
Quality	0.288	0.103	0.181	0.238	0.328	1.138	0.228
Material	0.11	0.097	0.123	0.073	0.1	0.503	0.101

3. Results and discussions

Here are the data processing results that have been manually conducted using the Analytical Hierarchy Process method. The first result is the geometric mean of each pairwise comparison matrix. Below is the table of geometric means between risk criteria for project completion selection, as shown in Table 3. Table 4 shows the geometric mean between risk sub-criteria for the contractor risk criteria, while Table 5 shows the geometric mean between alternatives for the experience risk sub-criteria.

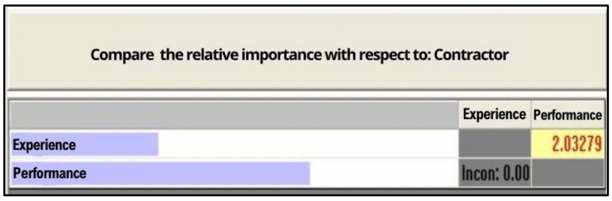
The following processing result is the pairwise comparison matrix for each hierarchy level. Table 6 shows the pairwise comparison matrices between risk criteria. Table 7 shows the pairwise comparison matrices between the sub-criteria of risk and the contractor risk criteria. Table 8 shows the pairwise comparison matrices between alternatives regarding the sub-criteria of experience risk. Next is the result of the priority matrix between risk criteria by normalizing and calculating priorities, as seen in Table 9. The results of the priority matrix between the sub-criteria of risk and the contractor risk criteria are shown in Table A1 (see Appendices). The results of the priority matrix between alternatives regarding the sub-criteria of experience risk are in Table A2 (see Appendices). After obtaining the priority results, the eigenvalue (λ_{max}) values between risk criteria are generated. The table of the eigenvalue matrix between risk criteria can see Table A3 (see Appendices). After calculating the maximum eigenvalue or λ_{max}, the consistency ratio is obtained as 0.077, meaning that the assessments provided by the experts are acceptable in their correctness. The table of the eigenvalue matrix between the sub-criteria of risk and the contractor risk criteria, see Table A4 (see Appendices).

After calculating the maximum eigenvalue or λ_{max}, the consistency ratio is obtained as 0.000, meaning that the assessments provided by the experts are acceptable in their correctness. The eigenvalue matrix between alternatives for the experience risk sub-criteria can be seen in Table A5 (see Appendices). After calculating the maximum eigenvalue or λ_{max}, the consistency ratio is obtained as 0.090, meaning that the assessments provided by the experts are acceptable in their correctness. Next, the global priorities are generated from the risk sub-criteria and overall global priorities, can be seen in Table A6 (see Appendices) and Table A6 (see Appendices). The results from the manual calculations will be continued with verification using Expert Choice 11 software. Below are the results from Expert Choice 11 software, see Fig. 2-4. The priority results and consistency ratio values from Expert Choice 11 software can be seen in Fig. 5-7. The global priority results using Expert Choice 11 software can be seen in Fig. 8.


Compare the relative importance with respect to:Selection of Project Completion

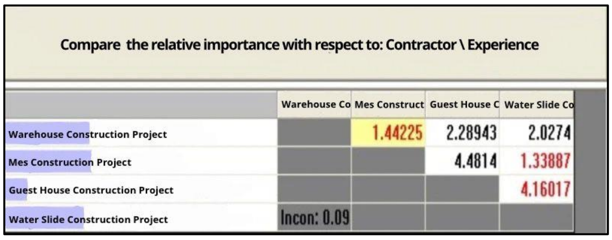
	Contractor	Financial	Environme	Quality	Material
Contractor		6.54213	6.80409	1.60915	4.21716
Financial			5.59344	1.0	1.06266
Environmental & Nature				3.47603	2.37126
Quality					3.27107
Material	Incon: 0.08				

Figure 2. Geometric mean between risk criteria for project completion selection


Compare the relative importance with respect to: Contractor

	Experience	Performance
Experience		2.03279
Performance	Incon: 0.00	

Figure 3. Geometric mean between sub-criteria of risk regarding contractor risk sub-criteria


Compare the relative importance with respect to: Contractor \ Experience

	Warehouse Co	Mes Construct	Guest House C	Water Slide Co
Warehouse Construction Project		1.44225	2.28943	2.0274
Mes Construction Project			4.4814	1.33887
Guest House Construction Project				4.16017
Water Slide Construction Project	Incon: 0.09			

Figure 4. Geometric mean between alternatives regarding the sub-criteria of experience risk

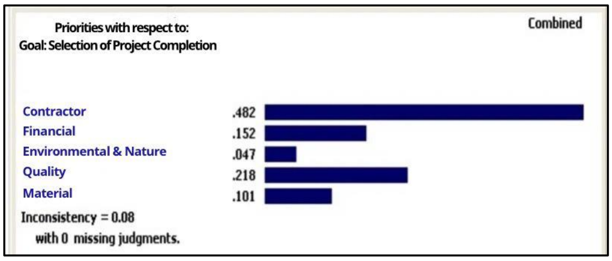


Figure 5. Priority and Consistency Ratio (CR) values between risk criteria for project completion selection

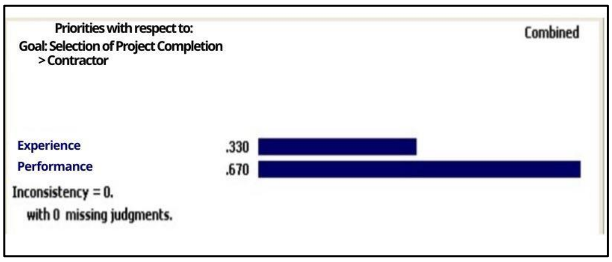


Figure 6. Priority and Consistency Ratio (CR) values between sub-criteria of risk and contractor risk criteria

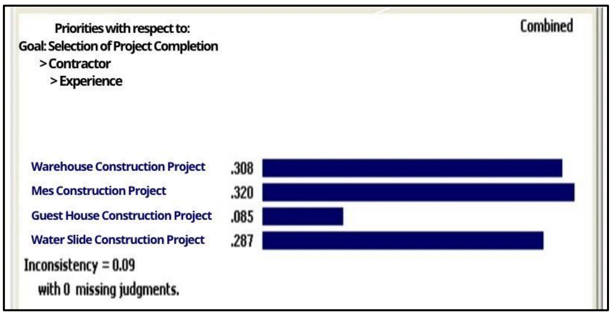


Figure 7. Priority and Consistency Ratio (CR) values between alternatives regarding the sub-criteria of contractor risk

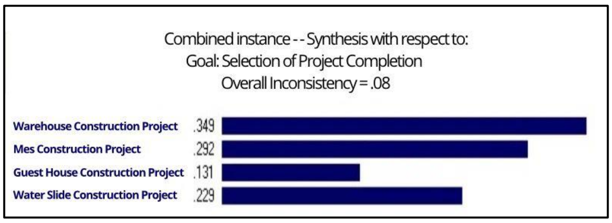


Figure 8. Global priorities

From the research conducted, it was found that the alternative project with the highest risk rating was the warehouse construction project, while the project with the smallest risk rating was the guest house construction project. The guest house construction project had the following sub-criteria risk ratings: experience risk at 1.3%, performance risk at 2.8%, project fund risk at 1.1%, additional budget risk at 0.6%, social disturbance risk at 0.5%, natural event risk at 0.2%, material quality risk at 1.3%, design quality risk at 1.7%, building quality risk at 2%, material delay risk at 0.9%, and material specification risk at 0.7%.

In actual conditions, the sequence of work on the company's construction projects is water slide construction, mess construction, guest house construction, and warehouse construction. However, this research suggests a different order: guest house construction, water slide construction, mess construction, and warehouse construction. This discrepancy arises because the company currently does not consider specific risk criteria but only evaluates the feasibility study and general construction project risks.

Based on the research results, the author proposes that the guest house construction project be prioritized for immediate completion compared to other alternative projects. This recommendation is based on the risk criteria used, which significantly influence construction project development. The guest house construction project has the smallest risk rating, amounting to 13.2%.

4. Conclusions

The conclusion drawn from this research is that the construction project risk criteria utilized include contractor risk, financial risk, environmental & natural risk, quality risk, and material risk. The ratings for the contractor risk criteria are 0.460 or 46%, financial risk criteria are 0.162 or 16.2%, environmental & natural risk criteria are 0.050 or 5%, quality risk criteria are 0.228 or 22.8%, and material risk criteria are 0.101 or 10.1%.

For the ratings of the sub-criteria, the experience risk sub-criteria is 0.152 or 15.2%, performance risk sub-criteria is 0.308 or 30.8%, project fund risk sub-criteria is 0.131 or 13.1%, budget increase risk sub-criteria is 0.031 or 3.1%, social disturbances risk sub-criteria is 0.035 or 3.5%, natural events risk sub-criteria is 0.015 or 1.5%, material quality risk sub-criteria is 0.08 or 8%, design quality risk sub-criteria is 0.075 or 7.5%, building quality risk sub-criteria is 0.072 or 7.2%, material delay risk sub-criteria is 0.059 or 5.9%, and material specification risk sub-criteria is 0.041 or 4.1%.

The construction project that has the lowest risk rating is a guest house construction project with a risk rating of 0.132 or 13.2%. Therefore, the guest house construction project is proposed to be completed first in selecting construction project completion.

Declaration statement

Nurul Ummi: **Conceptualization, Methodology, Software and Resources**. Putiri Bhuana Katili: **Supervision, Visualization, Investigation**. Virda Ayu Rahmawati: **Writing-Original Draft, Data Processing**. M. Hadi Setiawan: **Supervision**.

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Disclosure statement

The authors report there are no competing interests to declare.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Appendices

Table A1.
Priority matrix between sub-criteria of risk and contractor risk criteria

Sub Criteria	Experience	Performance	Total	Priority
Experience	0.330	0.330	0.659	0.330
Performance	0.670	0.670	1.341	0.670

TableA2.
Priority matrix between alternatives regarding the sub-criteria of experience risk

Alternatives	Warehouse Project	Mes Project	Guest House Project	Water Slide Project	Total	Priority
Warehouse Project	0.297	0.213	0.192	0.505	1.21	0.3
Mes Project	0.428	0.307	0.376	0.186	1.3	0.32
Guest House Project	0.13	0.069	0.084	0.06	0.34	0.09
Water Slide Project	0.146	0.411	0.349	0.249	1.16	0.29

Table A3.
Eigenvalue (λ_max) matrix between risk criteria

Criteria	Contractor	Financial	Environmental & Nature	Quality	Material	Total	Priority	λ
	0.46	0.162	0.05	0.228	0.101			
Contractor	1	6.542	6.804	1.609	4.217	2.649	0.46	5.76
Financial	0.153	1	5.593	1	1.063	0.846	0.162	5.224
Environmetal & Nature	0.147	0.179	1	0.288	0.422	0.254	0.05	5.101
Quality	0.621	1	3.476	1	3.271	1.178	0.228	5.176
Material	0.237	0.941	2.371	0.306	1	0.55	0.101	5.461
Total λ								26.722
Eigen Value (λ Max)								5.344
CI								0.086
RI, n =5								1.12
CR								0.077

Table A4.
Eigenvalue (λ_max) matrix between sub-criteria of risk and contractor risk criteria

Alternatives	Warehouse Project	Mes Project	Guest House Project	Water Slide Project	Total	Priority	λ
	0.302	0.324	0.085	0.289			
Warehouse Project	1	0.693	2.289	2.027	1.308	0.302	4.335
Mes Project	1.442	1	4.481	0.747	1.358	0.324	4.189
Guest House Project	0.437	0.223	1	0.24	0.359	0.085	4.201
Water Slide Project	0.493	1.339	4.16	1	1.227	0.289	4.248
Total λ							16.97
Eigen Value (λ Max)							4.243
CI							0.081
RI, n =4							0.9
CR							0.09

Table A5.
Global Priorities of Risk Sub-criteria

Global Priority Criteria		Experience	Performance	Project Funds	Budget Increase	Social Disturbances	Natural Events	Material Quality	Design Quality	Building Quality	Material Delay	Material Specification
Contractor	0,46	0,33	0,67	0	0	0	0	0	0	0	0	0
Financial	0,162	0	0	0,808	0,192	0	0	0	0	0	0	0
Environmental & Nature	0,05	0	0	0	0	0,707	0,293	0	0	0	0	0
Quality	0,228	0	0	0	0	0	0	0,35	0,331	0,318	0	0
Material	0,101	0	0	0	0	0	0	0	0	0	0,591	0,409

Sub Criteria Global Priority	0,152	0,308	0,131	0,031	0,035	0,015	0,08	0,075	0,072	0,059	0,041

Table A6.
Global Priorities

Alternatives Global Priority		Warehouse Project	Mes Project	Guest House Project	Water Slide Project	Calculation			
						Warehouse Project	Mes Project	Guest House Project	Water Slide Project
Experience	**0,152**	0,302	0,324	0,085	0,289	0,046	0,049	0,013	0,044
Performance	**0,308**	0,42	0,256	0,091	0,233	0,129	0,079	0,028	0,072
Project Funds	**0,131**	0,465	0,187	0,086	0,262	0,061	0,024	0,011	0,034
Budget Increase	**0,031**	0,187	0,462	0,197	0,154	0,006	0,014	0,006	0,005
Social Disturbances	**0,035**	0,564	0,216	0,14	0,08	0,02	0,008	0,005	0,003
Natural Events	**0,015**	0,48	0,218	0,112	0,19	0,007	0,003	0,002	0,003
Material Quality	**0,08**	0,366	0,296	0,168	0,17	0,029	0,024	0,013	0,014
Design Quality	**0,075**	0,079	0,371	0,223	0,327	0,006	0,028	0,017	0,025
Building Quality	**0,072**	0,169	0,31	0,281	0,239	0,012	0,022	0,02	0,017
Material Delay	**0,059**	0,441	0,322	0,147	0,09	0,026	0,019	0,009	0,005
Material Specification	**0,041**	0,318	0,37	0,171	0,141	0,013	0,015	0,007	0,006
Alternatives Global Priority						**0,356**	**0,286**	**0,132**	**0,227**