

# Optimizing Investment Selection for PPP Framework in the Transport Sector: A Risk Perspective

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**Abstract** The huge financial requirement of essential transport infrastructure system has challenged the availability of government funding. To fill the fiscal gap, public-private partnerships (PPP) framework has been applied as a promising mechanism. The success of PPP projects, however, is significantly influenced by a number of critical factors. Therefore, an optimum and comprehensive evaluation of projects, reflecting critical risks, supporting investment decisions, has been highly demanded by both the public and private sector. Various works, in previous studies, have been spreading scientific models assessing risks in the construction industry, and some of them focused on the area of PPP. However, the majority of published methods just concentrated on addressing and leveling risks, and there is a lack of application in evaluating and comparing different PPP projects, as investment options, with regards to key issues. Hence, in the situation of limited budget, the public and private partners may struggle with deciding the most potential alternative. To overcome this real-world challenge, this paper, by proposing a mathematical model, attempts to optimize investment selection by evaluating different projects' riskiness with the focus on transport projects. Different actual PPP transport projects in Vietnam were employed as case studies to analyze the practicality of the proposed application.

**Keywords** Decision Making, Public-Private Partnership, Investment Optimization, Risk Management

## 1. Introduction

Developing countries, especially in Asia, have experienced rapid economic development in recent years which has increased the demand for investment in infrastructure systems. However, the massive need to deliver transport infrastructure has put a strain on government budget. Consequently, PPPs are becoming inevitable. The success of PPP projects, however, is significantly influenced by a number of critical factors. Therefore, an optimum and comprehensive evaluation of projects, reflecting critical issues, to make investment decision, has been highly demanded by both the public and private sector. Identification of critical could be processed. However, decision makers may struggle with the overlap of benefits and drawbacks associated with key factors [6].

Approaches and techniques to resolve difficulties in assessing benefits and drawbacks of influential factors have been researched in a number of academic and practical works. Take research by Lee et al. [10] as an example, the theory of planned behaviour was developed to build a system supporting strategy makers in the area of real estate. Lee et al. attempted to clarify strategies suggested in Alternative Dispute Resolution (ADR) prototype by addressing the deficiency associated with a conceptual core. With more focus on a specific stage of the project life cycle, support vector form and elimination regression are utilized by Sonmez and Sözgen [22] to create strategies in the bidding process. Their system demonstrates the improvement as the number of input

factors required is reduced. This, in fact, enhances the generalizing process which proves significance in comparison to other frameworks applying linear regression and neural system. Evaluating previous academic and practical attempt in examining construction projects, Shevchenko et al. [20] emphasized that the multi-factor assessment including comprehensive qualitative analysis is essential. To support their statement, authors established an approach based on qualitative measurement weighing critical issues and influential factors, to suggest mitigation strategies.

In the literature of theories behind evaluation frameworks, Analytic Hierarchy Process (AHP), which is a multiple criteria decision-making technique, could be seen as a well-recognized model employed in numerous fields. This theory has been also applied to the construction industry. The theory was structured by Saaty [19] to convert subjective and linguistic evaluations to mathematical values by building pairwise comparisons between alternatives with regarding key criteria identified. Computed mathematical values build the foundation for decision makers to evaluate different options. One of the primary academic works adopting Saaty's theory to the construction industry was the research by Skibniewski and Chao [21]. Criticizing that traditional evaluation methods are unable to assess some aspects of specific projects, they attempted to remove the barriers in quantifying intangible features and risks connected with advanced building technologies. AHP was used to compare different intangible benefits and drawbacks of specific building technologies. Skibniewski and Chao also highlighted values of their framework compared to the conventional approach, which mainly focuses on economic features of the alternatives.

Exploring more particular areas of the construction industry, Analytic Hierarchy Process has been developed to manage key risks in PPP construction projects. For instance, the optimal proposal of a BOT contract for an individual construction can be highlighted using the AHP based-framework structuring a hierarchy of success drivers, built by Ababutain [1]. AHP application also proves its advantages in the research carried out by Zou et al. [27]. Authors observe that large and long investments in PPPs generate distinctive and dynamic issues which may not be sufficiently identified by conventional methods. Fuzzy sets are integrated into AHP system to identify and examine associated significant hazards through the project's life cycle. The integration of Fuzzy theory in their model is to reduce the risk of imprecise and uncertain data including crisp assessment. Compared to original AHP, Zou et al. model requires additional mathematical stage functioning defuzzification of fuzzy values. However, the high number of risk groups in their model may increase the inconsistency of judgment as Li et al. [11] suggested that the number of criteria in each layer should not be greater than five. Besides, defuzzification of fuzzy values to obtain risk weightings may lessen the

fundamental benefits of AHP which is to evaluate options with respect to all critical criteria.

Literature review reveals that a number of studies applied mathematical methods to the construction industry, and some of them attempted to apply in the area of PPP. However, the majority of published methods just concentrated on addressing and levelling risks, and there is a lack of application in comparing different PPP projects with focus on the transport sector, as investment options, with regards to key issues. Hence, in the situation of limited budget, the public and private partners may struggle with deciding the most potential alternative. Besides, previous methods have been considered as difficult to use in real practice [20]. To overcome this real-world challenge, this paper attempts to utilize original AHP in conjunction with Computation of risk score to reinforce investment selection by comparing the riskiness of different projects, concerning critical risks associated. Evaluation resulting from this developed model could be extremely valuable for both sectors in examining different options regarding risk perspectives. Different actual PPP transport projects in Vietnam are employed as case studies to analyse the practicality of the proposed application.

## 2. The Proposed Model

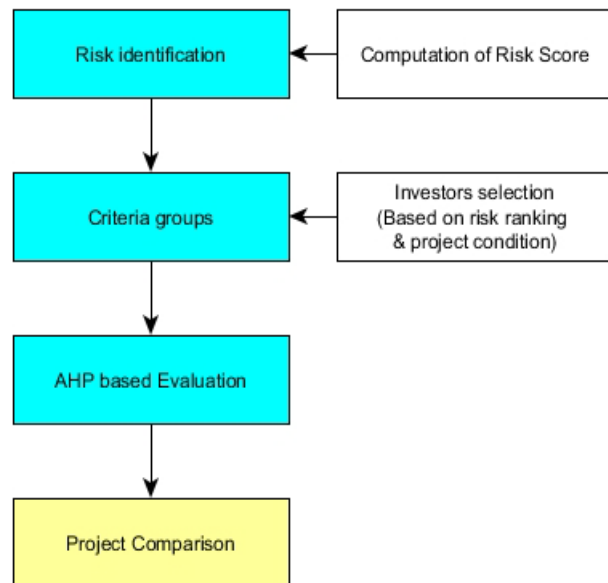


Figure 1. Process of Project Evaluation

### 2.1. Computation of Risk Score

Critical issues are analysed regarding their possibility of existence and the level of effect. Evaluations from experts are transferred to numeric inputs. Possibility of existence and the level of effect are evaluated based on 5-scale grade, namely 0.9, 0.7, 0.5, 0.3, and 0.1. These numbers present for the judgments of “very high”, “high”, “medium”, “low”, and “very low”, respectively.

Risk score can be computed as:

$$R_j^i = Po_j^i \times Ef_j^i \tag{1}$$

$Po_j^i$ : Possibility of existence of risk  $i$  evaluated by expert  $j$ .

$Ef_j^i$ : Level of effect of risk  $i$  evaluated by expert  $j$ .

$$R^i = \frac{\sum_{j=1}^n R_j^i}{n} \tag{2}$$

$n$ : Number of experts participated.

Mean value ranking of scores presents the critical level of the risks. In this paper, the importance of different participants is treated equally as [23, 12] concluded that there is no clear proof of significant difference between results using weighted and non-weighted input for different participants. The level of distance from the value to the mean is figured using Standard Deviation [5, 8, 16].

**2.2. AHP-based Investment Selection**

Optimal investment is selected based on pairwise comparison amongst options which, in this research, are different projects. Application of AHP allows evaluators to numerically rank alternatives based on comprehensive groups of critical issues. The configuration is demonstrated in Figure 2, and the detail of the proposed evaluation process is highlighted in Figure 3.

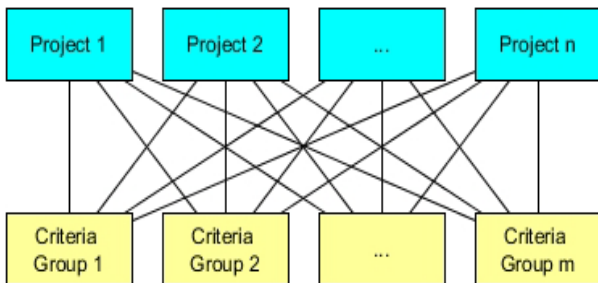


Figure 2. AHP structure in option evaluation

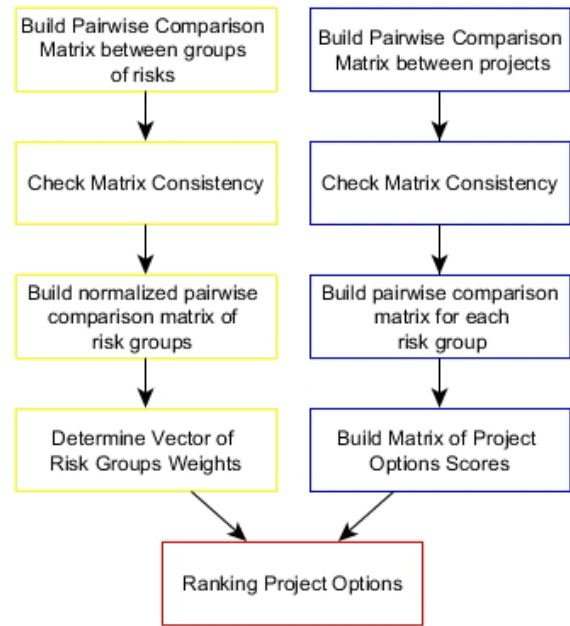


Figure 3. Process of evaluation

2.2.1. Vector of Risk Group Weights

Risks are categorized into  $n$  groups.  $A$  is an  $n \times n$  matrix built according to pairwise comparison amongst  $n$  groups.

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 2 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix} \tag{3}$$

$a_{ij}$  signifies the significance of risk group  $i$  compared to risk group  $j$ . The group  $i$  is more significant than  $j$  if the value of  $a_{ij}$  is greater than 1, and vice versa. It should be noted that  $a_{ij} \times a_{ji} = 1$ . The significance comparison is assessed according to scales indicated in table 1.

Table 1. Description of judgment

Numeric Input	Description
1	Two groups are equally significant.
3	One group is slightly more significant.
5	One group is strongly more significant.
7	One group is very strongly more significant.
9	One group is extremely more significant.

Table 2. Structure of comparison between groups

	Group 1	Group 2	...	Group n
Group 1	1			
Group 2		1		
...			1	
Group n				1

The significance judgment of different groups and structure of comparison are demonstrated in table 2 and 3. From these tables, the number of comparisons computed can be calculated as  $\frac{n(n-1)}{2}$  for the risk groups and  $\frac{m(m-1)}{2}$  for investment options.

**Table 3.** Structure of comparison between investment options

	Investment option 1	Investment option 2	...	Investment option m
Investment option 1	1			
Investment option 2		1		
...			1	
Investment option m				1

Using matrix A, the criteria weight vector is figured:

$$W = \begin{pmatrix} w_1 \\ w_2 \\ w_3 \\ \dots \\ w_5 \end{pmatrix} \quad (4)$$

Where:

$$w_i = \frac{\sum_{j=1}^m \bar{a}_{ij}}{m} \quad (5)$$

$$\bar{a}_{ij} = \frac{a_{ij}}{\sum_{h=1}^m a_{hj}} \quad (6)$$

More specifically, each member  $w_j$  of the vector  $W$  is found by finding the mean of each row in a new matrix which is built using members from matrix A, based on (5) and (6).

### 2.2.2. Matrix of Option Score

Each member of the matrix of the option displays the grade of option  $i_{th}$  regarding criteria (risk)  $j_{th}$ .

To identify the matrix of option score, the matrix  $B^j$ , an  $m \times m$  matrix with  $m$  is the number of investment option, needs to be built:

$$B^{(j)} = \begin{bmatrix} b_{11}^j & b_{12}^j & \dots & b_{1n}^j \\ b_{21}^j & b_{22}^j & \dots & b_{2n}^j \\ \dots & \dots & \dots & \dots \\ b_{n1}^j & b_{n1}^j & \dots & 1 \end{bmatrix} \quad (7)$$

Where  $b_{ik}^j$  displays the judgment of investment option  $k$  compared to investment option  $j$ , regarding the significance of criteria  $j$ .

$$b_{ik}^j \times b_{ki}^j = 1 \quad (8)$$

Matrix B is used to determine the matrix of option score (O) using the similar method of forming the vector of risk group weights presented in (5) and (6).

$$O = [O_1, O_2, \dots, O_m] \quad (9)$$

### 2.2.3. Investment Option Ranking

The ranking of investment options is discovered by forming the vector I, where:

$$I = O \cdot W \quad (10)$$

Data in vector I presents the score of each investment option, regarding criteria (risks), and the ranking of these values validates the riskiness level of the alternative options.

### 2.3. Data Experimentation

To validate the applicability of the proposed model in PPPs, statistics from actual PPP transport projects were examined. At the first stage, the identification and ranking of critical risks in Vietnamese PPP market were discovered based on Computation of Risk Score. Table 4 below demonstrates a list of risks, categorized by different groups, namely, Construction, Legal, Market, Operation, Political and Relationship Risks, based on in-depth literature review. Experts on the field are invited to evaluate these risks, according to the actual condition of the market, in terms of the possibility of existence and the level of effect.

**Table 4.** Risk groups

Group	Code	Risk
Construction	Co1	Unqualified product quality.
	Co2	Insufficient site safety.
	Co3	Land acquisition and relocation.
	Co4	Unrealistic feasibility study.
Legal	Le1	Lack of guarantees by the authority.
	Le2	Project approval process.
	Le3	Law changes.
	Le4	Tariff Restriction.
	Le5	Taxation Uncertainty.
Market	Ma1	Low transparency.
	Ma2	Insufficient fiscal capacity of investor
	Ma3	Inflation rate variation.
	Ma4	Interest rate variation.
Operation	Op1	High operation cost.
	Op2	Low operation quality.
	Op3	High Maintenance cost.
	Op4	Demand Fluctuation.
Political	Po1	Concession termination.
	Po2	Corruption and bribery.
Relationship	Re1	Inappropriate risk allocation.
	Re2	Low quality cooperation between parties.
Other	Oth	Negative nature events.

In the next steps, in order to apply AHP-based system, a set of options and a set of criteria are established. In terms of criteria, 10 critical risks from table 4 were chosen by investors to set up criteria groups. Investors are required to decide critical issues, based on the risk scores computed and real condition of the actual projects selected, to set criteria groups demonstrated in table 5.

With the purpose of evaluating different projects, 5 actual PPP transport projects, including 4 bridge projects and 1 highway project, are used as alternative investment options. In this paper, projects are named Project 1, Project 2, Project 3, Project 4, and Project 5. They are large scales projects in the transport sector in Vietnam and

have been highly criticized for critical risks associated. Projects are pairwise compared and linguistic measures are transferred into numbers following expression in table 1 to create the Matrix of option scores based on (4), (5), (6), (7) and (8).

### 3. Results and Discussion

The result of risk scores is demonstrated in table 5. These statistics reflect the general situation of Vietnamese PPP market in the transport sector. It can be seen that the most critical risks spread into all groups, excepting the relationship category.

**Table 5.** Ranking of risks in PPP project

Code	Risks	General			
		Score	Rating	St. deviation	P-value
Co3	Land acquisition and relocation	0.502	1	0.121	0.551
Le3	Project approval process	0.463	2	0.106	0.293
Ma3	Inflation rate variation	0.403	3	0.122	0.000
Op3	High Maintenance cost	0.374	4	0.098	0.962
Po2	Corruption and bribery	0.373	5	0.132	0.881
Op4	Demand Fluctuation	0.342	6	0.111	0.00
Ma2	Insufficient fiscal capacity of investor	0.337	7	0.105	0.018
Ma1	Low transparency	0.336	8	0.101	0.149
Co2	Insufficient site safety	0.324	9	0.112	0.000
Le5	Tariff Restriction	0.318	10	0.107	0.032
Ma4	Interest rate variation	0.314	11	0.107	0.000
Co1	Unqualified Product quality	0.310	12	0.100	0.002
Co4	Unrealistic feasibility study	0.291	13	0.086	0.015
Po1	Concession termination	0.268	14	0.084	0.000
Le1	Lack of guarantees by the authority	0.264	15	0.096	0.000
Re2	Low quality Cooperation between parties	0.258	16	0.089	0.000
Le4	Law change	0.244	17	0.126	0.000
Re1	Inappropriate risk allocation	0.229	18	0.143	0.000
Le6	Taxation Uncertainty	0.184	19	0.082	0.000
Op1	High Operation cost	0.174	20	0.103	0.000
Oth	Negative nature events	0.172	21	0.064	0.055
Op2	Low operation quality	0.151	22	0.006	0.002

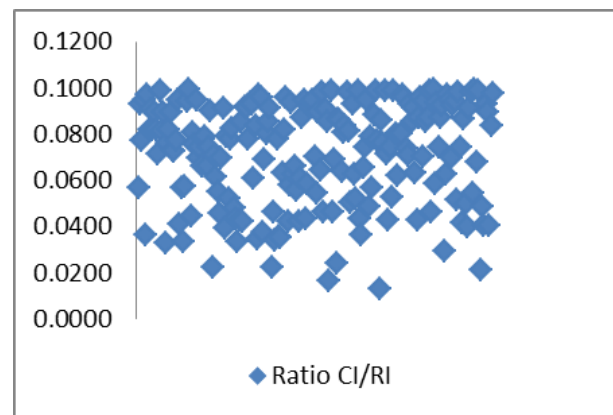
Amongst most critical subjects presented, Land acquisition and relocation (Co3), Project Approval Process (Le3), and Demand Fluctuation (Op4), and Financial capacity of investor (Ma2) are most emphasized by expert groups, although some of these issues did not present highest statistics. More specifically, Co3 is the most serious hazard. This finding is consistent with previous studies' results such as [24, 9] indicating that Co3 is one of the most worrying issues in Vietnamese construction plans. Co3 occurs as the demand of landowners is not satisfied during the acquisition and resettlement process. The conflicts contain financial issues and the living standard requirements in the resettled habitat. Project Approval Process (Le3) displays the concerns where the timing schedule does not follow the plan. The excessive approval process is evaluated as a result of the complex and multi-layers of the authorities. Reddy [18] clarified that multi-layers of the authorities create multiple approvals requiring too many documents which make approval process time consuming. Le3 can, in fact, change the project financial plan as variables fluctuate during the long lasting process [15]. Seriously, participants stated that Le3 seems to be external to investors. Demand Fluctuation (Op4) is the risk strongly emphasized by participants from both parties. Op4, in fact, is the critical issue for all PPPs in the transport sector [14]. The shortfall in demand can lead to a default of related partners. International experience in developing countries has shown similarity concerns as this reduction can be 48% compared to estimated level [7, 3]. Despite the fact that longer contract can be applied for specific reasons of shortfall, an extensive agreement brings other disadvantages, such as uncertainties and additional costs. Financial capacity of investor (Ma2) refers to the situation where investors' financial ability is inadequate for building and operating infrastructure. The loopholes in defining investor's financial capacity can come from incautious evaluation of financial reports and of projects in which financiers are invested in. Apart from above briefly analysed risks, other subjects and data in table 5 provide more insights of issues required to cautiously consider in making investment decision.

Based on risk ranking and the actual condition of five selected PPP projects, experts are required to form a set of criteria demonstrated in table 6. In this paper, the set of criteria is structured to spread all risk groups. This structure is expected to create the comprehensive evaluation regarding all aspects of projects. However, it should be noted that in practice, decision makers can choose a different number of risks as well as the categories for a specific target.

**Table 6.** Set of criteria

Group	Risk
Construction	Co1. Unqualified Product quality.
	Co3. Land acquisition and relocation.
Political and legal	Le3. Project approval process.
	Po2. Corruption and bribery.
Market	Ma2. Financial capacity of investor.
	Ma3. Inflation rate variation.
Operational	Op1. High Operation cost.
	Op3. High Maintenance cost.
Relationship	Re1. Inappropriate risk allocation.
	Re2. Low quality Cooperation between parties.

By setting up 5 groups of criteria, the number of pairwise comparison in the proposed framework is lowered to fit the scale of the current research. This is a strongly important point as the level of inconsistency is reduced and the time of analysing process is shortened.



**Figure 4.** Ratio of consistent matrices

The ratio of consistent statistic is displayed in figure 4. The matrix with lower ratio is measured as higher consistent, and a matrix is used if its ratio is not greater than 1. Inconsistent information was eliminated and the input for AHP system was only based on consistent statistics. In fact, the theory of AHP allows a certain level of variation as human is not consistent at all-time [18].

**3.1. Vector of Criteria Weights (w)**

From the data input, AHP system employs (4), (5), (6) to form the Vector of Criteria Weights (W):

$$W = \begin{pmatrix} \text{Construction} & 0.276 \\ \text{Political and legal} & 0.199 \\ \text{Market} & 0.136 \\ \text{Operational} & 0.268 \\ \text{Relationship} & 0.118 \end{pmatrix}$$

This vector describes that according to analyzers, in five selected projects, Construction risks, containing Unqualified Product quality Land acquisition and reallocation, are the most critical issues. Operation risks, including High Operation cost, High Maintenance cost, are positioned at the second position while Operational risks are evaluated as the least critical compared to other groups. This ranking meaning is different compared to ranking in table 4. While table 4 shows the general ranking regarding the market, the Vector of Criteria Weights demonstrates the weights of risk groups in the context of five specified projects selected.

### 3.2. Matrix of Option Scores

Similarly, using data collected and computing method described, the Matrix of Option Scores (O) is determined as:

$$O = \begin{pmatrix} 0.152 & 0.251 & 0.102 & 0.289 & 0.226 \\ 0.080 & 0.366 & 0.058 & 0.403 & 0.288 \\ 0.240 & 0.188 & 0.403 & 0.067 & 0.153 \\ 0.264 & 0.115 & 0.291 & 0.167 & 0.198 \\ 0.262 & 0.078 & 0.144 & 0.071 & 0.134 \end{pmatrix}$$

This matrix describes pairwise comparison between investment options (five actual projects) regarding each risk group, using (7), (8), (9). In order to find the comparison of options regarding all risk groups, Investment Option Ranking vector I is shown below.

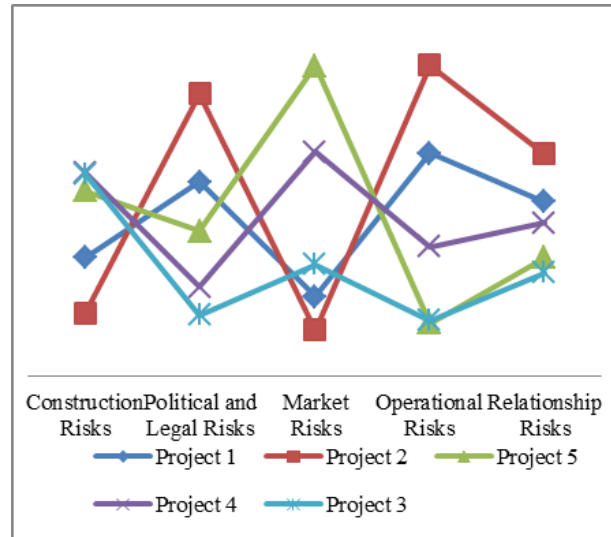
### 3.3. Investment Option Ranking

Using (10), the ranking of investment options is presented in table 7.

**Table 7.** Project option ranking regarding associated risks

Score	Investment options	Ranking
0.211	Project 1	2
0.246	Project 2	1
0.195	Project 5	4
0.204	Project 4	3
0.143	Project 3	5

Table 7 presents the riskiness level of different investment options. Statistic shows that project 2 is the riskiest alternative whereas project 3 is evaluated as the safest investment option. Values presented for project 1, project 2 and project 3 show smaller differences compared to the riskiness level of project 3. In reality, further evaluation of projects with a significant difference of riskiness level can be carried out.



**Figure 5.** Graphical representation of options' riskiness ranking

Table 7 and Figure 5 highlight the value of the proposed model in comparing alternatives. If a qualitative investigation was conducted only, decision makers may struggle with the overlap of benefits and drawbacks associated with each option. The comparison, therefore, may not be conclusive. With AHP and Computation of risk score, the proposed model transferred linguistic judgment to statistic comparison. Using graphical representation presented in Figure 5, investors will be able to have a quantitative evaluation of potential alternatives, not only in terms of the comprehensive riskiness but also with respect to each risk group. For instance, regarding Market risks, project 5 is the riskiest while in terms of Operational group, it is the least risky investment option.

Fundamental ideas of AHP in this paper are, to some extent, similar to previous research such as [12, 17]. However, the structure of the system is different. While [12, 17] utilize AHP to detect key risks, the model in this research is to compare the riskiness of different projects. Identification of critical risks is, instead, conducted using Computation of risks score. This, indeed, reduced the level of complexity of the system. Besides, the number of criteria in each level of AHP system in [12, 17] was high compared to the optimal statistic suggested by researchers [11]. The structure of AHP system in this paper is also significantly different from frameworks created by Zhang and Zou [26], Chang and Liu [4]. The difference is created as a result of the unique target. While [26, 4] employed AHP select proposal in different plans of one specific project, the model proposed in this paper is to select optimal investment option amongst different alternatives. Level of inconsistency may be reduced in research by [26, 4] by using integrated Fuzzy system. Nevertheless, the complexity of the system is certainly increased. The problem of inconsistent information, in this paper, is diminished by using the computation of risk score. This integration also provides evaluators with more insights

into critical threats during the process of forming the criteria set.

## 4. Conclusions and Future Research

This paper clarifies a mathematical model to optimize investment selection for PPP transport projects. The application of AHP in conjunction with Computation of Risk Score in evaluating of different PPP transport projects, as investment options, has not been done in earlier studies. In practice, optimization of investment selection is especially beneficial as its ability to support both sectors in defining the least risky investment options to implement in the PPP mechanism.

Based on AHP and Computation of Risk Score, a scheme was developed and five actual PPP transport projects were employed to demonstrate the proposed method. The results proved that the applied process can provide public and private partners not only with the scientific evaluation of the investment option's riskiness regarding comprehensive hazards but also the comparison of options' riskiness concerning each criteria category. It is worth pointing out that the number of risk groups and the number of risks in each group can be modified in reality based on the aspects that associated partners wish to investigate.

This proposed application, however, also contains its limitation. More specifically, AHP should be more efficient if the number of criteria (or sub-criteria) is not over five. This means the number of risks evaluated should not be over 25 risks divided into 5 groups. This might limit the number of risks in each level of the hierarchy structure. In order to overcome this limitation, selection of critical risks to create criteria group must be cautiously carried out. Future research may explore the limitation of this paper by developing a mechanism which is capable of analysing a higher number of risks by reducing inconsistent of AHP without increasing complexity of the evaluation system.

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