Risk allocation for infrastructure projects by PPPs – under environmental management and risk assessment mechanisms

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Abstract: Infrastructure is one of the pillars for achieving urban sustainable development socially, economically and environmentally, since it reflects the progress of countries. The importance, high cost, and insufficiency of available balanced governmental funding, particularly in developing countries, for these projects prompted many governments to implement such projects through public-private partnership (PPP). This will ensure high-quality service and low-cost advanced technology by activating the principle of value of money and through competition between local and international private sector companies in a framework of transparency. This paper discusses the contractual relations between parties of partnerships in these projects and mechanisms of distributing risks to parties during different phases of the project. It applies the analytical hierarchy process (AHP) through assigning risk indicators at relative weight resulting from the probability of occurrence of such risks, taking into consideration environmental management mechanisms to ensure projects' success in achieving the concept of sustainable development and its economic, social and environmental aspects.

Keywords: risk allocation; infrastructure projects; public-private partnership; PPP.

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1 Introduction

Egypts has adopted the recommendations of the 2015 UN Summit under the title (Transforming Our World: Sustainable Development Plan 2030), which had 17 goals. This research focuses on two goals, *goal 9:* build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation: and *goal 17:* strengthen the means of implementation and revitalise the global partnership for sustainable development.

This paper examines the concept of partnership between the state and the private sector in infrastructure projects. It applies the analytical hierarchy process (AHP) to ensure success through risk assessment of the project and study of the analysis method of these risks and their allocation to the parties of the partnership by measuring the risk indicators usage.

2 Research objectives and methodology

2.1 Research objectives

1. Identifying the concept and patterns of the state's partnership with the private sector in medium and long-term projects.
2. Studying the principles and mechanisms of sustainable environmental management associated with the phases of the project.
3. Identifying risk assessment indicators in partnership projects and methods of analysis.
4. Analysing the probability of these risks using the AHP.
5. Proposing a systemic framework to avoid the highest risk and mitigate its impact.

2.2 Research methodology

There will be identification of the concept of the state's partnership and the private sector in medium and long-term projects and its patterns using the inductive method. Then there will be a study considering the principles and mechanisms of sustainable environmental management related to the phases of the project, using the analytical method. Thereafter, the risk assessment indicators in partnership projects and methods of analysis will be identified and the probability of these risks will be analysed, using the analytical comparative method. Finally, a systemic framework will be proposed to avoid the highest risk and mitigate its impact, using the conductive method.

3 Sustainable environmental management

It is defined as: the management that achieves the optimisation of using the available natural resources to meet the needs of the present generation without affecting the opportunities of future generations (Glosson and Riki, 1994).

3.1 Environmental management considerations and mechanisms

In order to achieve sustainable development in an urban society, mechanisms and considerations of environmental management must be taken as indicators to determine the need of the community for the major development projects. The main indicators, which may affect implementing projects in an environmental frame, are shown in Table 1 (Holland, 2002).

Table 1 Mechanisms and considerations of environmental management

Indicator		*Steps for implementation*
Environmental impact assessment (EIA)	1	Classification
It is a mechanism for predicting the effects of various projects on the environment and human health and it is included in the decision-making process in development projects plans.	2	Determine zone
	3	Study of alternatives
	4	Project description
	5	Determine the effects
	6	Civil society participation
	7	Decision making
	8	Monitoring
	9	Revision
Environmental management system (EMS)	1	Determine need
Administrative and operational procedures through the development of a framework for an environmental contract covering the construction, management and operation phases	2	Describe need
	3	Execution
	4	O&M
	5	Monitoring
	6	Renewal
Urban indicators	1	Evaluate the present condition.
It is the method of obtaining basic information on the quality, problems, and patterns of the urban environment.	2	Monitoring the change within time.
Environmental communication	1	Governmental communication with the provider of the service.
It plays an important role in the development and implementation of effective environmental management programs.	2	Governmental communication with the customers.
Technology cost	1	Analysis of cost efficiency
	2	Analysis of (benefit/cost)

Source: Summarised from dnv gl (2015)

Therefore, the transformation of these indicators into risks classified and analysed at the various stages of the project will help in achieving environmental, economic and social sustainable development projects.

4 Infrastructure projects

Infrastructure projects are one of the pillars of achieving sustainable socio-economic and environmental development and a key indicator of the progress of countries. According to World Bank figures in 2015, the investment in infrastructure projects in the next five years till 2020 will reach 9 trillion dollars worldwide. The Middle East accounts for 9.2%, or about 830 billion dollars.

4.1 Infrastructure projects financing

Infrastructure projects have a special nature in terms of their size, complexity and high investment cost. Therefore, funding this type of project requires a huge amount of money. Sources of funding these projects are (Tagen, 2007):

- direct governmental finance
- financing through a tariff for the service
- funding from taxes
- funding by the private sector
- governmental funding by loans from local and international banks.

5 Public-private partnership

This term has multiple definitions introduced as follows:

1 *The World Bank defines public-private partnership (PPP) as*[1]: the partnership between the government sector and the private sector through cooperation between governmental entities, such as local authorities and central governments with private companies in many areas, such as health, education, infrastructure, and the degree of partnership varies in terms of responsibility and authority.

Medium and long-term infrastructure projects form an effective partnership between the state and the private sector through the implementation of the BOT system with various applications.

2 *The BOT concept:* UNCITRAL defines the BOT system as the contractual arrangement between a public-sector agency and private sector concerns whereby resources and risks are shared for the delivery of a public service or development of public infrastructure. Table 2 presents several mechanisms of PPP.

Table 2 Public private partnership models

Model	*Description of model*
BOT	Build, operate and transfer
BOT	Build, own and transfer
BOO	Build, own and operate
BOOT	Build, own, operate and transfer
BLT	Build, lease and transfer
BRT	Build, rent and transfer
BT	Build and transfer
BTO	Build, transfer and operate
BOR	Build, operate and renewal of concession

Source: Summarised from Nassar (2004)

Table 2 Public private partnership models (continued)

Model	*Description of model*
DBO	Design, build, operate
DBOM	Design, build, operate and maintain
DBMF	Design, build, manage and finance
DBFO/M	Design, build, finance and operate/maintain
MOT	Modernise, own or operate and transfer
ROO	Rehabilitate, own and operate
ROT	Rehabilitate, own and transfer
O&M	Operate and maintain

Source: Summarised from Nassar (2004)

5.1 Advantages of partnership systems

The advantages of partnership systems are defined as (Gahnem, 2009):

- addressing the lack of government funding
- sharing project risks with the private sector
- increasing the efficiency of operation and maintenance
- stimulate and develop the financial markets through offering the company's shares on the stock exchange
- increase job opportunities
- technology transfer
- the ownership of the assets remains in the hands of the government
- reducing administrative and financial corruption.

Table 3 Public-private partnership agreement contracts

Contract	*Description of contract*
Financing contract	Due to the large amount of financing for the construction of infrastructure projects, the project company is financing about 15% to 30% of the value of the project and the rest of the project budget is funded by external sources, for instance, banks and international financial institutions to complete the remaining funding for the implementation of the project.
Construction contract	The contract is signed by the project company with the contractor who responsible for the construction process. This type of contract is characterised by a small period if compared to the duration of other contracts, where it ranges duration from one to five years.

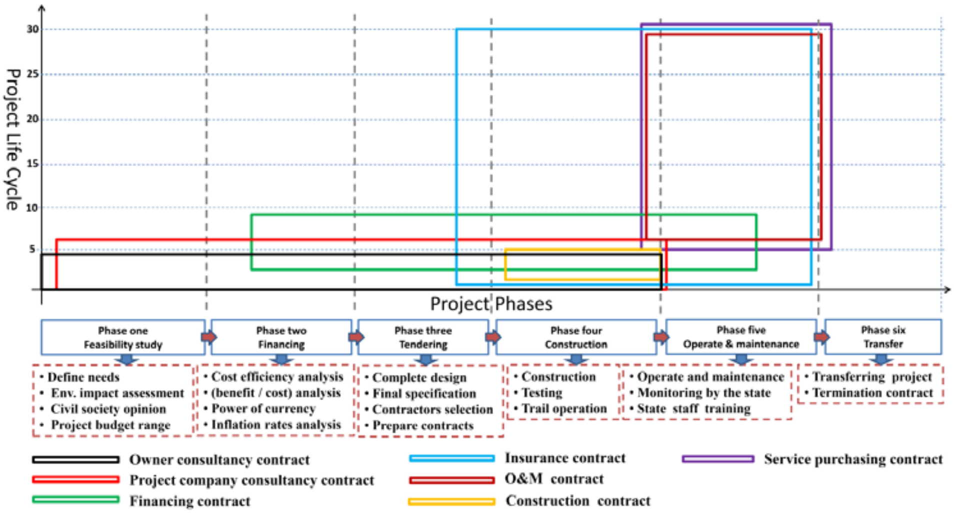
Source: Summarised from Tagen (2007) and by the author

Table 3 Public-private partnership agreement contracts (continued)

Contract	*Description of contract*
O&M contract	The contract is signed by the project company with one or more specialised operations and maintenance companies responsible for the operation and maintenance of the project during the concession period.
Supply contract	The contract is signed by the project company in order to purchase the necessary energy and raw materials for the long-term operation and maintenance of the project.
Service purchase contract	The contract is signed by the project company with the contracting authority to purchase the service or between the project company and the users directly through the direct sale.
Insurance contract	The contract is signed between the project company and one of the institutions specialised in the commercial insurance markets, such as investment guarantee agencies. This contract is signed against the risks of the project in the construction and operation phase, as well as political, commercial and natural risks.
Consultancy contract	Divided into two types, the first is signed between the state and the consultants who are specialised (technically, financially, legally) to monitor and follow up the various stages of project implementation. The second type is between the project company and consultants who have the same specialisation and tasks of the first contract but for the project company. The consultant is often a partner in the project company.

Source: Summarised from Tagen (2007) and by the author

Figure 1 Agreement contracts during concession period (see online version for colours)



Source: By the authors

5.2 Contractual relations in partnership projects (PPPs)

The project agreement is the basic contractual document of the partnership projects. The organisational framework deals with all the contracts of the project from the negotiation stage until transfer from the donor. Owing to the great complexity in the contractual relations in the partnership projects, it is necessary to identify the patterns of these contracts as in Table 3 and Figure 1.

5.3 Risks of PPP Projects

The assessment of the potential risks infrastructure projects in their various contractual stages throughout the life cycle of the project it is necessary to avoid the negative impacts that may lead to the failure of this type of project. *Risks* can be defined as those circumstances from the perspective of parties that have a negative impact on their goals that they expect to achieve from the project (Keçi, 2015).

5.3.1 Potential risk assessment

To ensure project success, potential risks must be assessed. Risk assessment includes the following steps (Beckers et al., 2013):

- *identification of risk* and classification of the degree of severity
- *understanding* the ability of state and stakeholders to deal with and manage risks effectively
- *framing the risk* and distributing it to stakeholders according to their ability to deal with it.

Risk identification can be conducted by many techniques; *interview/expert judgement* is used in this paper to identify risks. Table 4 states some of the risk identification techniques as discussed by Garrido et al. (2011).

Table 4 Risk identification techniques

Brainstorming	An idea generation group technique is divided in two phases: 1 idea generation phase, in which participants generate as more ideas as possible 2 idea selection phase, in which each participant supports his/her idea in order to convince the others.
Delphi technique	Delphi is a technique to obtain an opinion consensus about future events from a group of experts. It is supported by structured knowledge, experience, and creativity from an expert panel, presupposing that a properly organised collective judgment is better than an individual opinion.
Influence diagram	A graphical representation containing nodes representing the decision variables of a problem.
Interview/expert judgement	Unstructured, semi-structured or structured interviews individually or collectively conducted with a set of experienced project members, specialists or project stakeholders.

Source: Summarised by authors from Garrido et al. (2011)

Table 4 Risk identification techniques (continued)

Checklist	It consists of a list of items that are marked as 'yes' or 'no', and could be used by an individual project team member, a group or in an interview.
Flowcharts	A graphical tool that shows the steps of a process. This technique is applied for a better comprehension of the risks or the elements interrelation.
Questionnaire	It consists of questions at the attribute level, with specific tips, examples and questions for subsequent investigations.
SWOT analysis	It is a strategic planning tool used to evaluate the situation that involves a decision. Its application consists in the project evaluation in each of the four perspectives: strengths, weaknesses, opportunities, and threats.

Source: Summarised by authors from Garrido et al. (2011)

5.3.2 Potential risk allocation and evaluation

Total of (58) indicators were collected according to Table 5 and presented to specialised (10) experts in the infrastructure projects to rate the project phases from (1 to 6) and rate the risks under each phase from (1 to 10). Then, the geometric mean for each risk value given by the experts in the surveying sheets is calculated and risks with a rating more than 5 are chosen to be the priority risks as shown in Figure 2.

Table 5 Infrastructure project by PPP potential risks

RATING FROM 1 TO 10 ACCORDING TO THE SEVERITY OF THE RISK		
1	*Feasibility phase*	
	1.1	Changes in industrial law
	1.2	Changes in taxes law
	1.3	Import and export regulations
	1.4	Corruption and lack of respect for the law
	1.5	Inconsistencies in government policies
	1.6	Unstable government
	1.7	Transparency and confidence of the Gov
	1.8	Delay in project approvals and permits
	1.9	Expropriation/nationalisation of assets
	1.10	Expropriation of project profit
	1.11	The poor public decision-making process
	1.12	Environmental impact assessment
	1.13	Environmental management system

Source: Summarised by authors from John (2006), Salman et al. (2007) and Sarvari et al. (2014)

Table 5 Infrastructure project by PPP potential risks (continued)

	RATING FROM 1 TO 10 ACCORDING TO THE SEVERITY OF THE RISK	
2	*Financing phase*	
	2.1	Financial attraction of project to investors
	2.2	High finance cost
	2.3	Lack of creditworthiness
	2.4	Interest rate volatility
	2.5	Foreign exchange and convertibility
	2.6	Inflation rates
	2.7	Poor financial market
	2.8	Analysis of cost efficiency
	2.9	Analysis of benefit/cost
3	*Tendering phase*	
	3.1	Incomplete design
	3.2	Incomplete condition and specification
	3.3	Lack of subcontractor and supplier list
	3.4	Contractual gaps
	3.5	Competitive risks
	3.6	Inadequate experience in PPP
	3.7	Culture difference between partners
	3.8	Reject method of execution (proposed)
4	*Construction phase*	
	4.1	Land acquisition
	4.2	Distribution of responsibility and risk
	4.3	Different working methods/know-how
	4.4	Availability of appropriate labour/material
	4.5	Construction cost overruns
	4.6	Construction time delay
	4.7	Geotechnical conditions/ground condition
	4.8	Quality failure
	4.9	Change/modification of project scope
	4.10	Infrastructure for the project
	4.11	Force majeure
	4.12	Environment impact
	4.13	Weather impact

Source: Summarised by authors from John (2006), Salman et al. (2007) and Sarvari et al. (2014)

Table 5 Infrastructure project by PPP potential risks (continued)

	RATING FROM 1 TO 10 ACCORDING TO THE SEVERITY OF THE RISK	
5	*Operation and maintenance phase*	
	5.1	Operation cost overruns
	5.2	Maintenance cost overruns
	5.3	Unexpected price for maintenance material
	5.4	Bad quality of maintenance
	5.5	Change in O&M company
	5.6	Waste of maintenance material
	5.7	Technology /environmental pollution
	5.8	Tariff change
	5.9	Change in market demand
	5.10	Debt risk
	5.11	Gov. communicate with the provider of the service
	5.12	Gov. communication with the customers
6	*Transfer phase*	
	6.1	Renewal risk
	6.2	Transfer failure

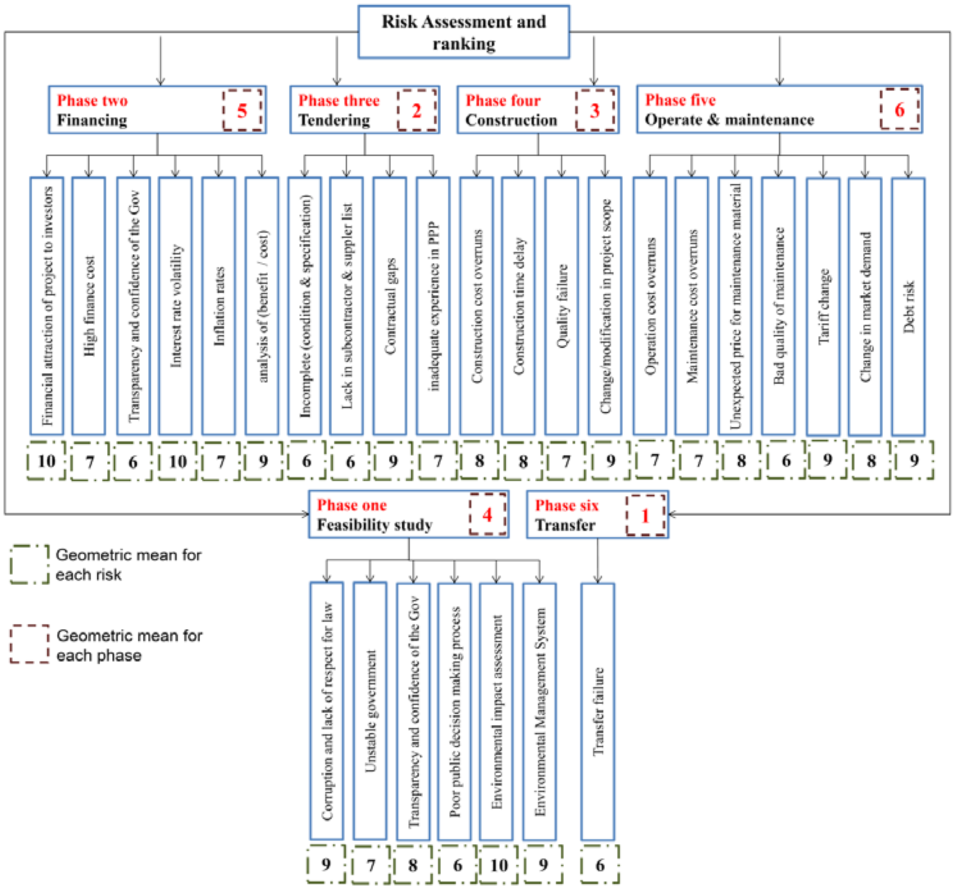
Source: Summarised by authors from John (2006), Salman et al. (2007) and Sarvari et al. (2014)

5.3.3 Analytical hierarchy process (Saaty and Vargas, 2012)

Thomas L. Saaty, as a simple and practical approach for decision-making, developed AHP. AHP is applied in multiple criteria group decision-making situations where a group with decision makers evaluate various elements by pairwise comparison (comparing items to one another at a time). In the comparison process, the decision makers use their judgments about the elements' relative importance. AHP was adopted in education, engineering, government, industry, management, manufacturing, personal, political, social, and sports (Vaidya and Kumar, 2006).

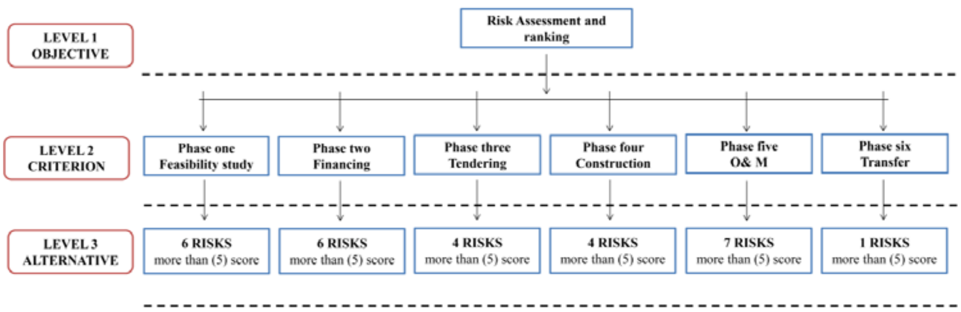
The main advantage of AHP is its capability to check and reduce the inconsistency of expert judgments. AHP involves assessing scales rather than measures; hence, it is capable of modelling situations that lack measures (e.g., modelling risk and uncertainty) (Aminbakhsh et al., 2013). The application of AHP technique starts by defining the problem and determining the kind of knowledge required, then structuring the decision hierarchy with the goal at the top, then deciding the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level which is usually a set of alternatives). Figures 2 and 3 show the hierarchy of the risks in this paper.

Figure 2 Risk hierarchy structure (see online version for colours)



Source: By the author

Figure 3 Risk hierarchy criteria (see online version for colours)



Source: By the author

The next step is constructing a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements directly below it. The pairwise comparison determines the relative importance between two compared items on a scale from 1 to 9. The pairwise comparison matrix $A = [a_{ij}]$ is a square reciprocal matrix of order n in which the importance of the element C_i with respect to the element C_j is determined by the element a_{ij}, $a_{ij} = 1/a_{ji}$ for $i \neq j$ and $a_{ii} = 1$ for all values of i, where i is the row number and j is the column number of any element in the matrix. The pairwise comparison matrices in this paper were constructed using questionnaires presented to a group of experts, and expert choice software was used for the calculations.

The relative weight of each element is calculated by calculating the eigenvector w for the matrix (vector of relative priorities for elements in the matrix). The consistency index (*CI*) is calculated using equation (1) for checking the consistency of the judgments in the matrix and then the consistency ratio (*CR*) is calculated using equation (2) and Table 5 and should not exceed 0.1, so that the judgments are satisfactory and accepted.

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{1}$$

CI is the consistency index, n is the order of the pairwise comparison matrix and $\lambda_{\max}$ is the eigenvalue.

$$CR = \frac{CI}{RI} \tag{2}$$

CR is the consistency ratio and should not exceed 0.1, *CI* is the consistency index and *RI* is the random consistency index obtained from Table 6.

Table 6 Average random consistency index

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: Summarised from Saaty and Vargas (2012)

Priorities obtained from the comparisons are used to weight the priorities in the level immediately below. Weighting by priorities is repeated for every element, then for each element in the level below to obtain the overall or global priority of the weighted values of that element are added. Continue this process of weighting and adding until obtaining the final priorities of the alternatives at the bottom-most level. The consistency ratio *CR* is checked for each matrix and should not exceed (0.1).

Table 7 shows the criterion matrix as an example. The matrix is filled by the experts through conducting pairwise comparisons in which value of '1' represents equal importance and '9' represents extreme importance. Taking the first row of the matrix, for example, the importance of project feasibility phase 'I' is determined with respect to each other phase. Feasibility phase 'I' had equal importance when compared to financing phase 'II'. Therefore, the cell is filled with '1' and is slightly more important when compared to the tendering phase 'III', thus, the cell is filled with '2'. But feasibility phase 'I' was found to be slightly less important when compared to operation and maintenance phase 'V'. Therefore, the cell is filled with '0.5'. These steps are repeated for the six project phases until the matrix is filled.

Table 7 Pairwise comparison matrix for project phases

	Feasibility (I)	*Financing (II)*	*Tendering (III)*	*Construction (IV)*	*O&M (V)*	*Transfer (VI)*
Feasibility (I)	*1*	1	2	1	0.5	4
Financing (II)	1	*1*	3	2	0.5	5
Tendering (III)	0.50	0.3333	*1*	1.00	2.00	1
Construction (IV)	1.00	0.50	1.00	*1*	0.50	3
O&M (V)	2.00	2.00	0.50	2.00	*1*	6
Transfer (VI)	0.25	0.20	1.00	0.33	0.1667	*1*

Source: By the authors

After finishing the pairwise comparison, the eigenvector of the matrix (relative weights) is calculated and consistency of the matrix is checked. Table 8 shows the approximate method of calculating the weights (eigenvector) using the geometric mean method. The geometric mean of each individual row in Table 7 is calculated and then divided by the sum of geometric means of all the rows to get the eigenvector.

Table 8 Approximate method of calculating eigenvector using geometric mean

Code	*Geometric mean of row (n^{th} root of product) = $(I*II*III*IV*V*VI)^{(1/6)}$*	*Eigenvector ω = geometric mean/ Σ (geometric means)*	*(Matrix A) * (eigenvector) Aω*	$\lambda_{max} = A\omega/\omega$
(I)	$\sqrt[6]{1*1.5*1*1.25*1*1}$ = 1.2599	1.2599/6.6895 = 0.1883	1.1657	6.1891
(II)	$\sqrt[6]{1*1*3*2*0.5*5}$ = 1.5704	1.5704/6.6895 = 0.2348	1.4887	6.3414
(III)	$\sqrt[6]{0.5*0.33*1*1*2*1}$ = 0.8327	0.8327/6.6895 = 0.1245	1.0032	8.0595
(IV)	$\sqrt[6]{1*0.5*1*1*0.5*3}$ = 0.9532	0.9532/6.6895 = 0.1425	0.8678	6.0901
(V)	$\sqrt[6]{2*2*0.5*2*1*6}$ = 1.6984	1.6984/6.6895 = 0.2539	1.7836	7.0251
(VI)	$\sqrt[6]{0.25*0.2*1*0.33*0.167*1}$ = 0.3749	0.3749/6.6895 = 0.0560	0.3644	6.5011
	Σ (geometric means) = 6.6895			$\lambda_{max} = 6.70105$

Notes: (I) – feasibility phase; (II) – financing phase; (III) – tendering phase; (IV) – construction phase; (V): operation and maintenance phase; (VI) – transfer phase.

Source: By the authors

- The consistency index (*CI*) using equation (1) = 0.134.
- The consistency index (*CR*) using equation (2) = 0.09.
- *CR* < 0.1 then the matrix is consistent.

Table 9 shows the relative weight of each phase of the project (eigenvector calculated in Table 8) sorted in descending order. Operation and maintenance is the most important phase according to the experts' opinion after analysing the surveying sheets by expert choice as seen in Table 9.

Table 9 Weight of project phases (level 2 – criterion)

Code	*Phase*	*Relative weight of criterion at level 2*
(V)	Operation and maintenance	0.253
(II)	Financing	0.234
(I)	Feasibility	0.188
(IV)	Construction	0.142
(III)	Tendering	0.124
(VI)	Transfer	0.056

Source: By the authors

The next step is to create pairwise comparison matrices, one for each of the project phases. Each matrix will have all the risks under the same phase compared with each other. The eigenvector for each matrix is calculated and the consistency of each matrix is checked as mentioned before to get the weight for each risk related to its phase. Table 10 shows the pairwise comparison matrix for risks under feasibility phase as an example, and Table 11 shows the approximate method of calculating the weights (eigenvector) using the geometric mean method for risks under the feasibility phase. Table 12 shows the relative weight of each risk in the feasibility phase (eigenvector calculated in Table 11) sorted in descending order. Environmental impact assessment is the most important risk in feasibility phase according to the expert's opinion after analysing the surveying sheets by expert choice software.

Table 10 Pairwise comparison matrix for feasibility phase

	A	*B*	*C*	*D*	*E*	*F*
A	*1.0*	1.5	1.0	1.25	1.0	1.0
B	0.6667	*1.0*	1.0	1.25	0.5	0.5
C	1.0	1.0	*1.0*	1.2	0.75	1.0
D	0.8	0.8	0.8333	*1.0*	0.5	0.75
E	1.0	2.0	1.3333	2.0	*1.0*	1.0
F	1.0	2.0	1.0	1.3333	1.0	*1.0*

Notes: A – corruption and lack of respect for the law; B – unstable government; C – transparency and confidence of the gov.; D – poor public decision-making process; E – environmental impact assessment; F – environmental management system.

Source: By the authors

Table 11 Approximate method of calculating eigenvector using geometric mean

	Geometric mean of row (n^{th} root of product) = $(A*B*C*D*E*F)^{(1/6)}$	*Eigenvector ω = geometric mean/ Σ (geometric means)*	*(Matrix A) * (eigenvector) Aω*	$\lambda_{max} = A\omega/\omega$
A	$\sqrt[6]{1*1.5*1*1.25*1*1}$ = 1.1105	1.1105/6.1271 = 0.1812	1.0940	6.0365
B	$\sqrt[6]{0.67*1*1*1.25*0.5*0.5}$ = 0.7699	0.7699/6.1271 = 0.1257	0.7668	6.1023
C	$\sqrt[6]{1*1*1*1.2*0.75*1}$ = 0.9826	0.9826/6.1271 = 0.1604	0.9710	6.0550
D	$\sqrt[6]{0.8*0.8*0.83*1*0.5*0.75}$ = 0.7647	0.7647/6.1271 = 0.1248	0.7560	6.0570
E	$\sqrt[6]{1*2*1.3*2*1*1}$ = 1.3218	1.3218/6.1271 = 0.2157	1.3039	6.0443
F	$\sqrt[6]{1*2*1*1.3*1*1}$ = 1.1776	1.1776/6.1271 = 0.1922	1.1673	6.0734
	Σ (geometric means) = 6.1271			$\lambda_{max} = 6.07$

Source: By the authors

- The consistency index (*CI*) using equation (1) = 0.0118.
- The consistency index (*CR*) using equation (2) = 0.094.
- *CR* < 0.1 then the matrix is consistent.

Table 12 Weight of project phases (level 3 criterion)

Code	*Phase*	*Risk*	*The weight of criterion at level 3 relative to its phase*
E	Feasibility	Environmental impact assessment	0.2157
F	Feasibility	Environmental management system	0.1922
A	Feasibility	Corruption and lack of respect for the law	0.1812
C	Feasibility	Transparency and confidence of the government	0.1604
B	Feasibility	Unstable government	0.1257
D	Feasibility	The poor public decision-making process	0.1248

Source: By the authors

The global weight of each risk is calculated by multiplying the relative weight of the risk by the weight of the risk parent phase. Table 13 shows the calculation of global weights for risks under the feasibility phase as an example.

Table 13 Global priority for risks under feasibility phase

Phase	*Risk*	*Weight at level 3 relative to its phase*	*The weight of phase at level 2*	*Global weight of risk*
Feasibility	Corruption and lack of respect for law	0.181	0.188	0.181 ∗ 0.188 = 0.034
Feasibility	Unstable government	0.126	0.188	0.126 ∗ 0.188 = 0.024
Feasibility	Transparency and confidence of the government	0.160	0.188	0.160 ∗ 0.188 = 0.030
Feasibility	Poor public decision-making process	0.125	0.188	0.125 ∗ 0.188 = 0.023
Feasibility	Environmental impact assessment	0.216	0.188	0.216 ∗ 0.188 = 0.041
Feasibility	Environmental management system	0.192	0.188	0.192 ∗ 0.188 = 0.036

Source: By the authors

Table 14 illustrates the weight for each risk related to its phase matrix, for the operation and maintenance risk group, the importance for the risks related to the weight are:

1 tariff change

2 change in market demand

3 debt risk

4 unexpected price for maintenance material

5 maintenance cost overruns

6 operation cost overruns

7 bad quality of maintenance.

Finally, Table 15 shows the global weight (priority) of each risk sorted in descending order.

Table 14 Weight of each risk (level 3 – alternatives)

CODE	*RISK NAME*	*W/L3*
	FEASIBILITY	
1.4	Corruption and lack of respect for the law	0.181
1.6	Unstable government	0.126
1.7	Transparency and confidence of the government	0.160
1.11	The poor public decision-making process	0.125
1.12	Environmental impact assessment	0.216
1.13	Environmental management system	0.192

Source: By the authors

Table 14 Weight of each risk (level 3 – alternatives) (continued)

CODE	*RISK NAME*	*W/L3*
	FINANCING	
2.1	The financial attraction of project to investors	0.188
2.2	High finance cost	0.144
2.4	Transparency and confidence of the government	0.161
2.5	Interest rate volatility	0.179
2.6	Inflation rates	0.141
2.9	Analysis of benefit/cost	0.186
	TENDERING	
3.2	Incomplete (condition and specification)	0.230
3.3	Lack in subcontractor & suppler list	0.222
3.4	Contractual gaps	0.313
3.6	Inadequate experience in PPP	0.234
	CONSTRUCTION	
4.5	Construction cost overruns	0.251
4.6	Construction time delay	0.248
4.8	Quality failure	0.211
4.9	Change/modification in project scope	0.290
	O&M	
5.1	Operation cost overruns	0.130
5.2	Maintenance cost overruns	0.131
5.3	Unexpected price for maintenance material	0.155
5.4	Bad quality of maintenance	0.116
5.8	Tariff change	0.165
5.9	Change in market demand	0.157
5.10	Debt risk	0.157
	TRANSFER	
6.2	Transfer failure	0.040

Source: By the authors

Table 15 Global priority (level 1 – objective)

C/RANK		*RISK NAME*	*W/L 1*
5.8	1	Tariff change	0.045
5.9	2	Change in market demand	0.043
5.10	2	Debt risk	0.043
5.3	2	Unexpected price for maintenance material	0.043
4.9	3	Change/modification in project scope	0.041
1.12	4	Environmental impact assessment	0.040

Source: By the authors

Table 15 Global priority (level 1 – objective) (continued)

C/RANK		*RISK NAME*	*W/L 1*
2.1	4	The financial attraction of project to investors	0.040
2.9	4	Analysis of benefit/cost	0.040
3.4	5	Contractual gaps	0.039
2.5	6	Interest rate volatility	0.038
5.2	7	Maintenance cost overruns	0.036
1.13	7	Environmental management system	0.036
5.1	7	Operation cost overruns	0.036
4.5	7	Construction cost overruns	0.036
4.6	8	Construction time delay	0.035
2.4	8	Transparency and confidence of the government	0.035
1.4	9	Corruption and lack of respect for law	0.034
5.4	10	Bad quality of maintenance	0.032
2.2	11	High finance cost	0.031
2.6	12	Inflation rates	0.030
1.7	12	Transparency and confidence of the government	0.030
4.8	12	Quality failure	0.030
3.6	13	Inadequate experience in PPP	0.029
3.2	13	Incomplete (condition and specification)	0.029
3.3	14	Lack in subcontractor and suppler list	0.028
1.6	15	Unstable government	0.024
1.11	16	Poor public decision-making process	0.023
6.2	17	Transfer failure	0.003

Source: By the authors

6 Conclusions

In conclusion, the applied AHP in multiple criteria group decision-making situations was discussed in this paper. This method which entails a group of decision makers evaluates various elements by ‘pairwise’ comparison. It based the application on identified patterns of the state’s partnership with the private sector as time-related (in medium and long-term projects). The project life cycle was associated with the principles and mechanisms of sustainable environmental management. The decision-making mechanics were based on risk assessment indicators and analysing the probability of these risks. Finally, it developed a systemic framework to avoid the highest risk and mitigate its impact based on all previous factors. This framework was tested, using suggested relative weights for its application, taking into account the environmental management consideration and mechanisms.

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Notes

1 http://ppp.worldbank.org/public-private-partnership/.