Chapter

Risk Analysis in Early Phase of Complex Infrastructure Projects

Esra Tepeli

Abstract

Infrastructure construction projects are complex with a very long life-cycle, a complex organizational plan, a complex resource management, technical complexities, contractual complexities and macro-environmental factors. The complexity of an infrastructure project leads to the existence of interdependent risks, which are hard to anticipate and control. As the investment is major for these types of projects, the risks and opportunities are critical to the project success or failure, the risk factors need to be identified and analyzed before any decision-making process. While upfront planning is important, not all events and scenarios can be foreseen as the project can take several years to complete and may involve many companies and stakeholders. In this planning stage of the project, a robust risk analysis method is indispensable for identifying and analyzing the major risk and opportunity factors. In this paper, a formalized multi-criteria decision-making process is developed based on a strategic risk analysis in a complex environment: (1) in a very early stage and at a strategic level, (2) before the contracting phase in order to develop a risk allocation plan and negotiate it with the project owner.

Keywords: risk management, complex projects, infrastructure projects, environmental risk analysis, risk breakdown structure, multi-criteria analysis, decision-making process

1. Introduction - risk management context for complex infrastructure projects

Risk is defined, according to ISO 31000, as the effect of uncertainty on the objectives to be achieved [1]. The last decades have been marked by notable developments in terms of infrastructure construction projects but also by unfulfilled objectives which challenge the construction industry. Strong gaps are identified in terms of organization and general management at the project level, in particular relating to the interfaces between the project actors whose specific objectives may be different or even contradict. This results in a persistent difficulty for controlling risks with the increase of the number of stakeholders. These difficulties are further heightened for complex and strategic projects. A complex and strategic project is a project that requires during its life cycle, an organization and a specific approach to manage the project, risk and opportunities [2]. Whether a project is classified as complex and strategic depends on several criteria. These criteria may relate to the organization or company which manages the project such as the level of fit with the general strategy, the main objectives of the organization, its culture and financial state. Other criteria relate to the nature of the project such as the commercial environment, the financial plan, the brand image, the organizational plan, and the technical features. External criteria are the environmental factors such as politic factors, legal factors, social factors, international aspects when the project is abroad. External factors occur outside the organization but can lead to internal changes and are, for the most part, beyond the control of the organization [3].

Infrastructure construction projects belong to this type of strategic and complex projects as they focus on the development and maintenance of services, facilities, and systems. Infrastructure construction projects include bridges, power & energy infrastructures, roads and railroads, airports, water infrastructures and dams, and waste management plants. Infrastructure projects have a long life-cycle including the maintenance-exploitation phase. Moreover, infrastructure projects must manage complex organizational aspects, complex resource management, and complex technical and financial aspects. Such projects can be also affected easily by the environmental factors, for instance the macro-economic conditions or the politic factors of the country. These types of projects are major investment projects and can be funded by private companies, publicly, or combined as a public-private partnership (a collaboration of government entities and private sector companies). Because of all these aspects, the risk and opportunities to the project are critical and need to be identified and analyzed before any decision-making process takes place. The ITA/AITES report highlights how risk management is important in the early phase of complex tunneling projects. The report recommends a set of good practices with include the shared analysis of the risk of both the client and the potential contractors [4].

In addition, the contractual framework of infrastructure projects can be very complex; it leads to redefining the role of the project actors, their responsibilities and missions. Risk management is essential in order to identify and assess the risk and opportunity events throughout the project life cycle. Especially for the private contractor, identification of the risk and opportunity events is crucial in the early phase of the project. In this phase, the candidate contractor needs to make a strategic decision for making an offer to the tender for the project or to pull out. This decision will lead to the initial risk assessment, then offer submission with a detailed risk analysis to be able to negotiate the contract terms with the client, and to define the risk allocation plan when contract awarded [5, 6].

The risk analysis in the early phase enriches the decision-making process. The risk analysis provides rational arguments which help to avoid or mitigate the probability or impacts of negative risk events and to increase the probability and impacts of positive events which are called opportunities [7]. However, literature review shows a gap in terms of risk identification and assessment methods concerning the early phase of a complex infrastructure project [2]. The project risk identification and assessment methods in the literature consider the risk factors in a static way. Therefore, these methods have some limitations in term of adaptability and even applicability to the early phase. The difficulty is that, in the early phase of a complex project, the identification of risk events can be limited because of a scarce level of information about the project and uncertainties. With the project progresses, more information becomes available, and more precise risk identification and assessment can be performed. For this reason, developing a formalized risk management method in the early phase is necessary to identify and analyze the major risks and opportunities of an infrastructure project and to make a strategic decision for the project's future.

Therefore, the purpose of this paper is to propose a strategic and environmental risk analysis process which is applicable to the early stage and at the strategic level of an infrastructure project. In the process, the environmental risk and opportunity factors are analyzed using a formalized multi-criteria approach. This approach supports to take an optimal strategic decision for assigning some resources to a given (possible) project and later, after preliminary studies, to adequately consider detailed studies. For the client or project owner, the strategic decision corresponds to the validation of the project program and starting the step "call for tenders." For the contractor, the strategic decision corresponds to the decision to respond to the call for tenders or to pull out of the project. Then, various possible projects can be compared in order to choose and pursue the most beneficial ones, allocate the project risk optimally and control it as the project progresses. On the other hand, the strategic and environmental risk analysis process can be adapted to the evolving nature of the infrastructure project, refining the first identification of risk factors performed in the early phase of the project [8]. In the method proposed, special attention will be paid to the point of view of a private contractor with the option of adapting for multiple stakeholders if necessary.

In this perspective, Section 2 of the book chapter provides the modeling of the strategic and environmental risk analysis process in early phase of complex infrastructure projects. In the development of the process, we emphasized on a hybrid approach for the identification and analysis of risk factors which combines literature analysis, case studies of complex infrastructure projects and the Delphi technique. In Section 3, the qualitative risk assessment method and decision-making process will be explained following the principles presented in Section 2.

2. Strategic and environmental risk analysis of a complex infrastructure project

We call "project risks" as the effects of uncertainties on the project objectives in terms of time, cost, performance, quality and safety. The project risks must be managed and controlled optimally in order to achieve the project objectives. Project risk management consists of identifying risk events and analyzing them qualitatively and quantitatively. Risk analysis qualifies and/or quantifies the probability of occurrence of an identified risk and/or opportunity event and their possible negative and/or positive impact(s) on the project objectives. Finally, action plans can be proposed to the risk to a level where the residual risk is accepted. In the development of an effective risk management method, it is necessary to take into account the project objectives, the project's environmental factors and integrate the vision of the various project partners. The most classic objective of an infrastructure construction project is to manage and optimize costs and deadlines, to ensure quality and performance [9–11]. In the context of infrastructure projects, performance is understood over the long term, because it may include the entire period of maintenance and operation.

For analyzing the environmental factors in a complex project environment and understanding different stakeholders' perspectives, we followed a hybrid analysis methodology with:

1. a literature review about risk management in the early phase of infrastructure projects,

2. case studies of infrastructure projects for identifying the main risk and opportunity factors,

3. Delphi-technique sessions for understanding the perspectives of the main project stakeholders (project owner, principal contractor, consultant and other

contracted parties) about risk management in a complex project environment in the early phase, defining the process of the strategic and environmental risk analysis method, identifying and assessing main risk and opportunity factors in the early phase of the project.

The results of the literature review and the case studies revealed that in most cases of complex and strategic infrastructure projects, the main risk and opportunity factors are financial, economic, political-legal, organizational, managerial, strategic and technical factors, payment issues, construction design and technical risk, and inappropriate risk allocation across the project stakeholders [12–15].

Then, Delphi-technique sessions were carried out with the main stakeholders of infrastructure projects such as project owner, contractor, financial partners, and external stakeholders for defining a risk management strategy in the early phase.

Following the literature review, analysis of case studies and the Delphi-technique sessions, we developed the strategic and environmental risk analysis method with an external and internal risk analysis. The external risk analysis carries out the identification and analysis of the risk and opportunity factors related to the external environment of the project, such as political-legal, economic, social, technological, contractual, competitive, client's influence and force majeure factors [15, 16]. In parallel, the internal risk analysis identifies and analyzes the risk and opportunity factors related to the internal environment of the project facing the project stakeholders. These factors comprise the stakeholders' financial situation, technical strength/weakness, organizational dynamics, relationships with other project stakeholders, project client's influence, project competitors' influence and the interface between project stakeholders [17–19].

The life cycle of infrastructure construction projects can be very long with multiple phases such as feasibility studies, preliminary studies, technical studies and design, competitive dialog or tendering and contracting, administrative procedures, construction, maintenance and operation (**Figure 1**). The aforementioned risk analysis in the early phase of the project which includes strategic studies and the project's feasibility is essential for managing the risk across the whole project's life [20–21]. In these phases, project managers do not have detailed information about the project, they have only information about project scope, program and project environment. For this reason, the identification and assessment of project risks can be very challenging because of the lack of knowledge and uncertainties. Therefore, a strategic and environmental analysis can be used for identifying the main risk and opportunity factors to take a strategic decision about the project's future (GO or STOP decision) and to define a risk allocation strategy or/and preliminary risk response planning before the contracting phase (**Table 1**). The goal is to qualify the threats-opportunities and strengths-weaknesses of the project related to its environment [22–24]. Then, we detailed the risk and opportunity factors related to the external and internal environment of an infrastructure project and defined a

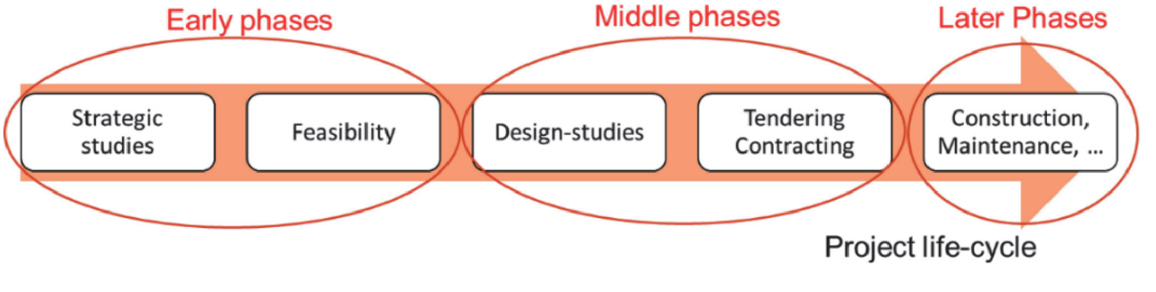

Figure 1.
Life-cycle of an infrastructure construction project.

Phase(s)	Strategic studies - feasibility
Objective	Realize the strategic analysis and environmental analysis before the decision GO/STOP for the project, identify the risk and opportunity factors
Available information	Project scope, program, localization of the project, project life-cycle, client, commercial environment, contract information, budget, competitive environment, technical information, financial information, project life-cycle, organization, resource information, external and internal environmental factors of the project
Method /tool	Strategic and environmental analysis

Table 1.
Strategic and environmental analysis in the early phases of an infrastructure construction project.

qualitative risk assessment method to analyze the overall risk level of the project in the early phase.

Following the literature review and the Delphi-Technique sessions with the project stakeholders, in the first step, a set of risk factors is defined for both the external and internal environment as part of the strategic and environmental risk analysis process (**Table 2**). The objective is to identify the risk and opportunity factors of a complex project related to the external and internal environment, to carry out a qualitative or quantitative risk assessment in the early phases, and to make a strategic decision for the project's future. Then, a risk breakdown structure is developed with factors and sub-factors, and a qualitative evaluation method is proposed for the risk and opportunity assessment.

Project environmental factors	
1. External environmental factors	**2. Internal environmental factors**
1.1. Political-legal	2.1. Project life-cycle
1.2. Contractual	2.2. Organization
1.3. Economic	2.3. Technical features
1.4. Social	2.4. Financial features
1.5. Client influence	
1.6. Competitive environment	
1.7. Technology	
1.8 Force Majeure	

Table 2.
External and internal environmental factors.

2.1 External environmental factors

In project management, it is common to analyze the factors that are closer and more directly related to management, such as time management, resource or cost management. It will be more difficult to control the more general factors from the exterior perimeter to the project. It is therefore essential to be aware of the environmental factors that can represent restrictions and favorable circumstances in order to propose accurate risk response planning for the project success. This analysis will also apply to the project risks related to adverse environmental factors. In all cases, organizations must be prepared to mitigate the negative risk. The external environment covers the factors that can influence the project from outside the organizations [25–27]. We can distinguish the macro-environment from the micro-environment. The macro-environment analysis focuses on the broad scope that will influence the project directly or indirectly, such as political, legal, macro-economic and social factors. The micro-environment analysis highlights the interactions and relationships with other project stakeholders, the influence of the stakeholders on the project, the competitive analysis, and the technological factors. The interface between the macro-environment and the micro-environment includes lobbying, conventions, and contracts which determine the effects of the global environmental factors on the project perimeter.

In the external environmental risk and opportunity analysis, a risk breakdown structure has been elaborated with the external environmental factors and sub-factors of an infrastructure construction project (**Table 3**).

In the external environment eight risk factors are defined: (1.1) political-legal, (1.2) contractual, (1.3) economic, (1.4) social, (1.5) client influence, (1.6) competitive environment, (1.7) technology, and (1.8) force majeure.

Then, a qualitative multi-criteria evaluation takes place for assessing the risk level of the external environmental factors. As a result, a qualitative risk matrix is obtained. Each criterion is evaluated on a qualitative 5-level Likert scale [28]: High Risk, Risk, Neutral, Opportunity, High Opportunity.

Political-legal factors determine the extent to which government and government policy may impact on an organization or a specific industry as well as trade, fiscal and taxation policies, employment legislation, consumer law, trade regulation, health and safety regulations, unexpected legislation and international rules.

Contractual factors consider complexities and uncertainties which belong to the general contractual frame such as the repartition of roles and missions of stakeholders, responsibility limits and risk allocation between the stakeholders.

Economic factors influence the economy and its performance, which can give impacts on the organization and its profitability directly such as interest rates, unemployment rates, material costs and foreign exchange rates.

Social factors focus on the social environment and help an organization to understand its clients' needs and requirements. Social factors can include changing education levels, cultural trends, attitude changes and changes in lifestyles, and social security factors such as sabotage against the project, mobbing, strikes, criminal activities.

The influence of the stakeholders on the project and the relationship between project stakeholders is another external environmental factor. Mainly the client or project owner's needs must be analyzed for the project success. For the client influence factor, nine sub-factors are defined: image of the client, relations with the client, communication frequency with the client, feedback from last common projects, experience of the client for complex and strategic construction projects, project management assistance of the client, project budget allowance, financial capacity, and organizational change management-acceptance for value propositions.

The competitive factor is very challenging in the early phase for analyzing the strengths and weakness of the competitors. For the competitive environment, five sub-factors are defined: the number of competitors, competitor's size, technical capacity, financial capacity, and partners.

Technological factors indicate the rate of technological innovation and development that could affect a market or industry such as changes in technology, automation, new methods of distribution, manufacturing, logistics, research, and development. For the technology factor, three sub-factors are defined: technical difficulties, special products or innovations requested for the project and material price fluctuations.

Force majeure factor refers to an event or effect that can be neither anticipated nor controlled. There are dozens of circumstances or events that can be classed as examples of force majeure: earthquakes, hurricanes, explosions, floods, energy blackouts, epidemic diseases and war.

1. External environmental factors	Sub-factors	Qualitative evaluation				
		HIGH RISK	RISK	NEUTRAL	OPPORTUNITY	HIGH OPPORTUNITY
1.1. Political-legal						
1.2. Contractual						
1.3. Economic						
1.4. Social						
1.5. Client influence	1.5.1. Image of the client					
	1.5.2. Relations with the client					
	1.5.3. Communication frequency					
	1.5.4. Feed-back					
	1.5.5. Experience of the client					
	1.5.6. PM assistance					
	1.5.7. Project budget					
	1.5.8. Financial capacity of the client					
	1.5.9. Change management ability					
1.6. Competitive environment	1.6.1. Number of the competitors					
	1.6.2. Competitor's size					
	1.6.3. Technical capacity					
	1.6.4. Financial capacity					
	1.6.5. Partners					
1.7. Technology	1.7.1. Technical difficulties					
	1.7.2. Special products					
	1.7.3. Material price fluctuation					
1.8. Force majeure						

Table 3.
Factors and sub-factors of the external environment of a complex project.

2.2 Internal environmental factors

The internal environment covers the risk and opportunity factors that can influence the project from the inside of the organization or company. These factors comprise inter alia the features and complexities related to long project life-cycle, project management issues associated with a long life-cycle, and organizational structure. The organizational structure issues include resources, competences, communication and decision-making flows, corporate missions, corporate culture, technical features and financial properties of the project [17–19].

In the internal environmental risk and opportunity analysis, a risk breakdown structure has been elaborated with the internal environmental factors and sub-factors of an infrastructure project (**Table 4**).

In the internal environmental analysis four factors are defined: (2.1) project life-cycle, (2.2) organization, (2.3) technical aspects, and (2.4) financial aspects.

Then a qualitative multi-criteria evaluation takes place for assessing the risk level of the internal environmental factors. As a result, a qualitative risk matrix is obtained. Each sub-factor is evaluated on a qualitative 5-level Likert scale alike as in the external environmental analysis: High Risk, Risk, Neutral, Opportunity, High Opportunity.

The project life-cycle can be long for an infrastructure construction project with several phases, tasks, and milestones. For the project life-cycle factor, six

2. Internal environmental factors	Sub-factors	Qualitative evaluation				
		HIGH RISK	RISK	MEDIUM	OPPORTUNITY	HIGH OPPORTUNITY
2.1. Project life-cycle	2.1.1. Strategic studies					
	2.1.2. Design-Technical studies					
	2.1.3. Call for tenders-Contracting					
	2.1.4. Construction					
	2.1.5. Maintenance-Exploitation					
	2.1.6. Demolishing-Removal					
2.2. Organization	2.2.1. Project Management Office					
	2.2.2. Engineering Department					
	2.2.3. Construction Department					
	2.2.4. Financial Department					
	2.2.5. Legal Department					
	2.2.6. Architecture Office					
	2.2.7. Sub-contractors					
	2.2.8. Consultants					
	2.2.9. Maintainers					
	2.2.10. Suppliers					
2.3. Technical aspects	2.3.1. Technical complexity					
	2.3.2. Mastery of constructive technique					
	2.3.3. Innovation proposition					
	2.3.4. Resource availability					
	2.3.5. Quality management					
	2.3.6. Safety management					
2.4. Financial aspects	2.4.1. Financial resource					
	2.4.2. Project cost estimation					
	2.4.3. Profitability forecast					
	2.4.4. Reserves					

Table 4.
Factors and sub-factors of the internal environment of a complex project.

sub-factors are defined: strategic studies, design-technical-price studies, call for tenders-contracting, construction, maintenance-exploitation, and demolishing-removal. The objective is to evaluate the risk and opportunity factors related to the project planning and time management, the cost management for the whole project life-cycle, the complexity of tasks, and the knowledge and/or available information about the project features.

The structural organization is composed of various stakeholders with multiple organizational structures, services, and partners. There are risk and opportunity factors related to stakeholder's availability, competence, degree of experience, collaboration skills, communication skills, coordination, managerial skills and management of project resources such as resource availability, resource acquisition and transportation, resource planning and optimization.

For the organization factor, ten sub-factors are defined: Project Management Office (PMO), engineering department, construction department, financial department, legal department, architecture office, sub-contractors, consultants, maintainers, and suppliers.

For the technical features, six sub-factors are defined: technical complexity of the project, mastery of construction techniques, innovation proposition, resource availability, quality management, and safety management.

For the financial features, we can consider the factors related to financial resources, project estimation, profitability, managerial costs, and reserves. For the financial features factor, four sub-factors are defined: financial resource, project cost estimation, profitability forecast and, reserves.

3. Qualitative multi-criteria risk analysis and decision-making process

3.1 Qualitative multi-criteria risk analysis

In the definition of the project execution model, a stakeholder uses resources for realizing the project activities or tasks [2]. According to this definition, the main dimensions of a project are the project stakeholders or the structural organization, the project life cycle and the resources. The internal and external environmental factors can induce risk events which may have positive and negative consequences for the project stakeholders, resources and the project progression. In the end, these factors may impact the project objectives in terms of time, cost, quality, and safety [4] (**Figure 2**).

For instance, the macro-economic factors can influence the project funding or raw material costs; a politic or social factor can influence a stakeholder behavior; a legal factor can influence the project progression; the behavior of the public client can influence the relational flows between the stakeholders; positive public opinion about the project can induce opportunities for the project's realization.

Following the modeling of the risk breakdown structure of the environmental factors, the next step is to define a qualitative risk evaluation method to assess the external and internal environmental risk factors and to develop a global risk evaluation for the project. This assessment can be conducted at two levels:

1. in an early stage and at a strategic level for taking a strategic decision about the project,

2. before the contracting phase in order to develop a risk allocation plan.

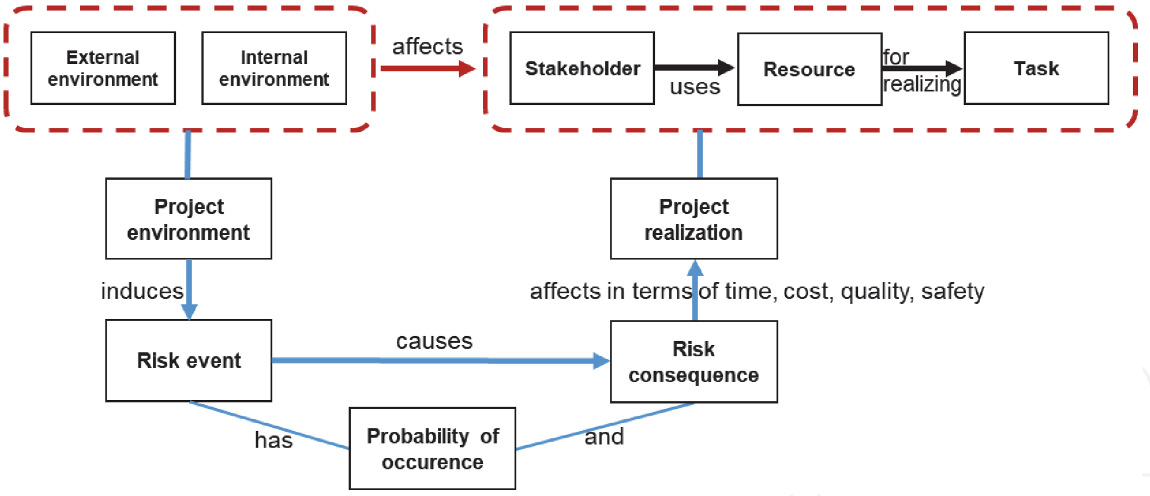

Figure 2.
Effects of environmental factors on the project realization.

The first assessment corresponds to a qualitative multi-criteria risk analysis, as part of a formalized decision-making process. The definition of the multi-criteria analysis is based on the risk breakdown structure of both sets of environmental risk factors and sub-factors. The qualitative risk assessment is realized by evaluating the environmental factors and the sub-factors in the Likert-scale from High Risk (HR) to High Opportunity (HO) as indicated in **Table 5**. In this way, we obtain a qualitative risk matrix for the external and internal environmental factors. An example of a risk matrix with the qualitative evaluations is illustrated in **Table 6**.

After codifying the Likert scale using the values in **Table 5**, the arithmetic mean "N*EnvExt*" is calculated as the risk evaluation score for the external environment of the project. Alike, the arithmetic mean "N*EnvInt*" is calculated as the risk evaluation score for the internal environment of the project. The following equations are used:

Evaluation of external environmental factors:

$$N_{EnvExt} = \frac{1}{8}\sum_{i=1}^{8} N_{cr-env-ext_i} \tag{1}$$

where $Ncr\text{-}env\text{-}ext_i$ is the evaluation score for each external environmental factor.

For the factors such as "Client influence" where there are multiple sub-factors attached, the factor's evaluation "$Ncr\text{-}env\text{-}ext_i$" is calculated using the following formula:

$$N_{cr-env-ext_i} = \frac{1}{n_{env-ext}}\sum n_{env-ext_i} \tag{2}$$

Risk/opportunity level	Score	Color code
High risk (HR)	1	Red
Risk (R)	2	Orange
Neutral (N)	3	Yellow
Opportunity (O)	4	Green
High opportunity (HO)	5	Dark Green

Table 5.
Qualitative scale for risk and opportunity levels.

1. External environmental factors	Sub-factors	Qualitative evaluation				
		HR	R	N	O	HO
1.1. Political-legal			X			
1.2. Contractual		X				
1.3. Economic			X			
1.4. Social						X
1.5. Client influence	1.5.1. Image of the client				X	
	1.5.2. Relations with the client				X	
	1.5.3. Communication frequency				X	
	1.5.4. Feed-back				X	
	1.5.5. Experience of the client				X	
	1.5.6. PM assistance			X		
	1.5.7. Project budget		X			
	1.5.8. Financial capacity of the client				X	
	1.5.9. Change management ability			X		
1.6. Competitive environment	1.6.1. Number of the competitors	X				
	1.6.2. Competitor's size		X			
	1.6.3. Technical capacity		X			
	1.6.4. Financial capacity		X			
	1.6.5. Partners		X			
1.7. Technology	1.7.1. Technical difficulties		X			
	1.7.2. Special products		X			
	1.7.3. Material price fluctuation		X			
1.8. Force majeure				X		

Table 6.
Qualitative risk matrix for environmental risk and opportunity factors.

where n*env-ext*$_i$ is the evaluation score for each external sub-factor i, and n*env-ext* is the total number of the sub-factors attached to an external factor.

Evaluation of internal environmental factors:

$$N_{EnvInt} = \frac{1}{4}\sum_{i=1}^{4} N_{cr-env-\mathrm{int}_i} \tag{3}$$

where N*cr-env-int*$_i$ is the evaluation score for each internal environmental factor.

For the internal factors with multiple sub-factors attached, the calculation of the evaluation score N*cr-env-int*$_i$ for an internal environmental factor is similar as in the external environment analysis. The evaluation score of an internal environmental factor i is calculated using the following formula:

$$N_{cr-env-\mathrm{int}_i} = \frac{1}{n_{env-\mathrm{int}}}\sum n_{env-\mathrm{int}_i} \tag{4}$$

where n*env-int*$_i$ is the evaluation score for the internal sub-factor i, and, n*env-int* is the total number of the sub-factors per internal factor.

For the risk matrix example illustrated in **Table 6**, the resulting evaluation score for the "external risk environment" of the project is:

$$N_{EnvExt} = 2.55 \tag{5}$$

If the resulting evaluation score N*EnvExt* is smaller than 3, the external environment of the project is qualified as "risky" according to the qualitative scale of Table. If the resulting evaluation score evaluation score is larger than 3, the environment is qualified as "opportune". The evaluation score N*EnvInt* for the internal environment of the project can be calculated and assessed in a similar way.

3.2 Decision-making process

Following the analysis of the project's external and internal environments, the risk evaluation scores help to assess if the project will be opportune or not for the company. Based on this assessment, the company can take a go/no go decision for the project. **Figure 3** shows the decision-making process. If the evaluation score of the external environmental analysis "N*EnvExt*" is larger than or equal to 3, we look at the evaluation score "N*EnvInt*" of the internal environmental analysis. If this evaluation score is also larger than or equal to 3, the project is qualified as an "opportune" project. An opportune project means that the project shows more opportunities than risk aspects. A GO or ACCEPT decision is proposed with a risk monitoring option.

If the evaluation score of the internal environmental analysis "N*EnvInt*" is smaller than 3, a brainstorming session is organized for discussing if the company can deal with the project risk when necessary risk mitigation actions are planned. If the project managers agree that there are more opportunities than risk and the negative risk impacts could be reduced with the application of action plans, they could propose a GO or ACCEPT decision.

If the evaluation score N*EnvExt* is smaller than 3, we look at the evaluation score N*EnvInt*. If this score is also smaller than 3, the project is qualified as a "risky" project, which means that there is more risk than opportunities and a STOP or REJECT decision is generally proposed. If the evaluation score is larger than or equal to 3, a brainstorming session is organized for discussing if the company can develop action plans to mitigate the negative risk impacts.

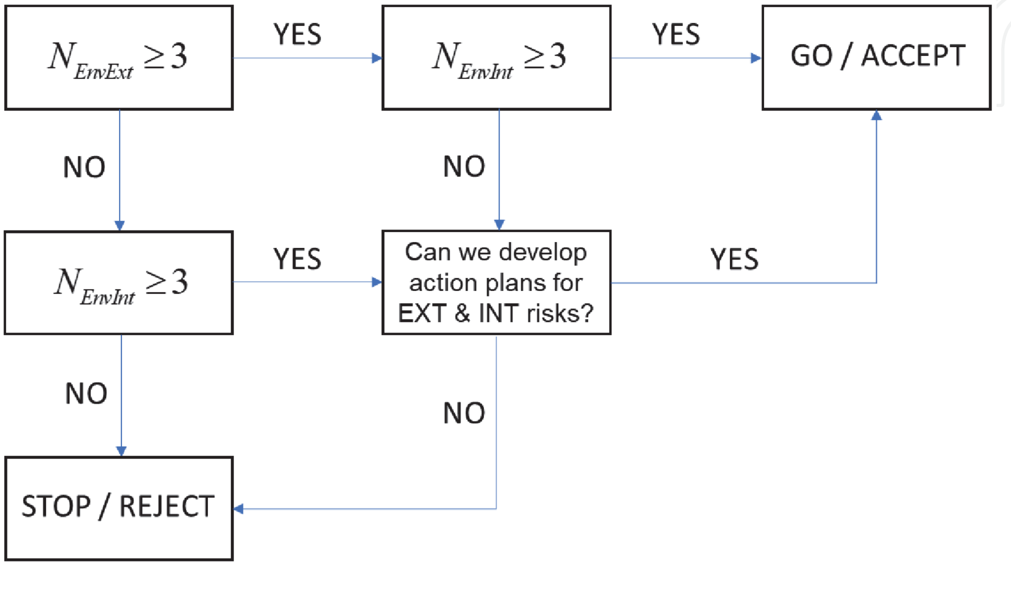

Figure 3.
Decision-making process for the environmental risk analysis.

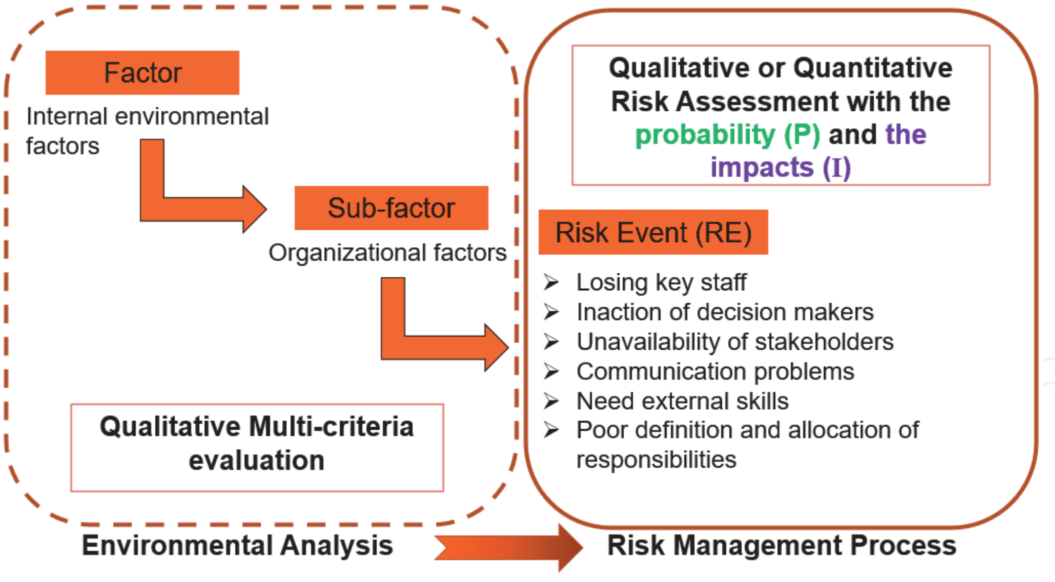

Figure 4.
Detailed risk analysis in later phases of the project based on the environmental analysis.

The strategic and environmental analysis permits to identify and assess the main opportunity and risk factors in the early phase of the project. With the help of the multi-criteria analysis, project managers can also compare multiple projects and choose the most beneficial ones for the corporate strategy.

When a GO or ACCEPT decision is taken for the project, a response planning should be developed for the risk factors deemed critical. For instance, if a potential risk is identified attached to the contractual frame of the project, this factor should be analyzed in detail. Action plans should be developed to minimize the possible legal and administrative disruptions and prepare a realistic risk allocation agreement.

In the later phases, with the project progress, more information will be available about the project. Then, the strategic and environmental risk analysis of the project evolves towards a formalized risk management process. In this approach, the risk and opportunity factors can be identified and analyzed in a more detailed structure and tracked during the project life-cycle [2, 5].

In **Figure 4** some risk events examples are illustrated, attached to the organizational factors in the internal environmental analysis, such as inaction of decision makers, unavailability of stakeholders, communication problems, poor definition and allocation of responsibilities. In this step, a formalized risk register can be developed with the risk and opportunity events, the qualitative or quantitative assessment of probability of occurrence and possible impacts in terms of cost, delay, quality and safety. Then, a risk response planning can be developed and implemented in order to mitigate the risk during the project life-cycle.

4. Conclusion

For complex projects such as infrastructure construction projects, implementing a risk management strategy is essential to achieve the project goals. It is essential to be aware of project risks related to environmental factors in order to develop the appropriate action plans. Structuring a risk management strategy that includes not only risk events but also opportunities will be beneficial for the business strategy. However, developing a robust and reliable risk management strategy can be quite difficult for complex infrastructure construction projects. Complex projects may have a long and complex life-cycle, multiple stakeholders with a complex organizational plan, and contractual complexities. For these types of projects, the identification and assessment of risks is a difficult task and may depend upon the project's characteristics and the project's environmental conditions. Since complex projects can also be of strategic importance, the early project phases play an important role in risk analysis. During this period, the project managers should analyze whether the project could be beneficial or risky to the company, carry out strategic and feasibility studies, and decide to continue or not with the project. In this step, a robust decision-making strategy should be developed for the project's future, which includes a careful analysis of the risk and possible opportunities. However, the lack of precise information about the project and a large number of uncertainties may lead to certain limitations in the reliable identification and analysis of the risk and possible opportunities during the early project phase.

This paper outlines a formalized process of strategic and project environmental risk analysis at a very early stage of a complex infrastructure construction project. Examples show how this methodology has been put into practice.

In the process, the external and internal environmental risk and opportunity factors are identified and analyzed in a formalized approach to develop an optimal strategic decision to allocate certain resources to a prospective project and later, after preliminary studies, effectively consider the project for detailed studies. Then, a qualitative multi-criteria analysis is undertaken in order to evaluate the risk and opportunity factors attached to the external and internal environment of the project and to assess the overall risk level in the early project phases. At this level, highlighting the presence of uncertainties and the lack of detailed information about the project, the risk evaluation scores cannot present a firm conclusion on the overall risk assessment. However, the methodology can provide important elements to the project management and allows risk managers to discuss in detail the risk and possible opportunities to the project. In fact, the strategic and environmental analysis should be considered as a project analysis element before any decision-making process. The environmental risk analysis may provide insight for a realistic negotiation of risk allocation with the other project stakeholders. In addition, the process may provide an accurate global vision of the project and a good understanding of the project's environmental factors. The integration proposed in the model between environmental analysis and risk management received good feed-back from project experts when applying he process in operational cases.

During later project phases, the project and risk managers can perform a more detailed risk identification and analysis; identify risk and opportunity events in a more detailed breakdown structure, assess them qualitatively and quantitatively, provide risk response planning and monitor risks during the project life-cycle. The analysis can be conducted more thoroughly when the project data permits. The formalized approach integrated into the environmental risk analysis process can provide feedback on the project, and this information could be used in the analysis of future projects.

Author details

Esra Tepeli
University of Versailles, Paris Saclay, France

*Address all correspondence to: tepeli.esra@gmail.com

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