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Risk Assessment for Large-Scale Transport Infrastructure Projects

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Abstract. The identification of risks in the planning phase of a project and the arrangement of impact values has become a fundamental basis of today's various construction projects. Despite robust and well-planned projects, unexpected problems will likely emerge in any stage of the project if possible risks are not identified and assessed beforehand. Therefore, this process has become a requisite in increasing the success as well as minimizing the problems of a project. Large-scale transport infrastructure projects (LSTIPs), technologically equipped projects, meet the essential needs of the recent era but also bring about numerous risks such as financial, technical, managerial, political, economic, natural or legal. Hence, being exposed to such risks in the planning and construction stage of LSTIPs, could lead to negative consequences in the fate of the project. This study aims to develop a conceptual framework which provides a pathway for the planning phase and to offer risk lists and their priority orders that reinforce the construction phase. These aims were achieved by identifying the risk factors that could arise in European and Middle Eastern LSTIPs and detecting significances of the risks according to these types of projects. Data collection was performed through a substantial review of literature and a questionnaire conducted to contracting firms and civil engineering consultancies operating in Europe and the Middle East. According to the findings, the comparison between the leading risks encountered in European and in Middle Eastern LSTIPs revealed that two of the regions were confronted with both similar and different risks. Europe and the Middle East's foremost common risk factor is the financial strength of the client listed under the financial category. When regions are considered individually, Europe gives prior importance to the resource availability risk factor in the economic category whereas increased material cost located under the same category is the primary risk factor for the Middle East. As a result, the data obtained from this research study could be deployed as a standardized risk list in the planning stage of forthcoming LSTIPs as well as a guideline for the assessment phase of priority orders. Furthermore, this study suggests a further and detailed investigation on mitigating risks that occur in LSTIPs.

1. Introduction

In the past ten years, Large-scale transport infrastructure projects (LSTIPs) have become a major area of interest and have gained prior importance in construction companies and firms located in Europe and the Middle East. These projects have also received considerable attention in the literature from scholars



and researchers. Based on previous studies, the lengthy period of time devoted to planning and implementing the project trigger the emergence of multiple risks in LSTIPs [1]. In large-scale civil engineering and architectural projects, collaboration is the key for success. In other words, different participants from different organizations endeavour to work together in projects. Research that has been carried out on risks in LSTIPs involve feasibility risk assessment of transport infrastructure projects [2], reflection of issue of risk in transport infrastructure projects [3] and cost overruns in LSTIPs [4]. Throughout the process of a project, stakeholders are confronted with different types of risks, ranging from business or financial risks to environmental risks. It may not be possible to eliminate all these risks in a project; however it is necessary to effectively identify and assess all risks in advance for the successful accomplishment of a project. Regarding this matter, the main purpose of this study is to present a conceptual framework which helps firms take action in mitigating or eliminating risks in the planning phase of LSTIPs operating in Europe and the Middle East. By identifying risks that could occur in these two regions and determining significances of the risks in these projects, this study also aims to create a guideline for effectively managing risks in further research studies conducted in Europe and the Middle East.

The structure of this study is formed as follows; first of all, an expansive review of literature regarding LSTIPs was carried out and risk categories and factors were identified. Secondly, a questionnaire was prepared to gather demographic information of managers who work in firms running LSTIPs and to determine the priority orders of the risk factors that could arise in this type of projects. Thirdly, the results of the risks factors from the questionnaire were assessed and ordered by using the relative importance index method. Fourthly, the results for Europe and the Middle East were discussed separately and common risk factors were emphasized. Finally, the significances of risks factors for each region were obtained and a conceptual framework which guides firms operating in this area was developed.

2. Literature Review

This section emphasizes the importance of risks that could arise in LSTIPs, and focuses on the assessment of risks in these types of projects.

2.1. Large-scale Transport Infrastructure Projects

With the emergence of new technologies and the expansion of populations, transportation has become vital need. The evolution in transportation is inevitable as in the past twenty years' low capacity transportation modes have now transformed into a large capacity and rapid transportation era. In recent years, the implementation of LSTIPs has proved the significance given to transportation especially in highway, railway, tunnel, bridge and subway construction. The Rapid Transit railway project in Europe [5] and the Bridge project in the Middle East [6] are two prominent examples that highlight the importance of such projects in these two regions. Obviously, the projects fulfilled in Europe and the Middle East have had a large contribution to public transportation and the economy. However, it is apparent that risks will likely emerge from long-term and costly in LSTIPs.

2.2. Risk assessment in Large-scale Transport Infrastructure Projects

In the light of the literature, various methods and techniques regarding risk assessment have been applied to these kinds of projects. Diab et al. [7] used chi-square, likelihood ratio chi-square and fisher's exact test as risk assessment techniques to improve highway construction project performance. Similarly, Abdollahzadeh and Rastgoo [8] applied fault tree and event tree analysis methods based on fuzzy logic to assess risks in a bridge project. Additionally, Vishwakarma et al. [9] study imposed the relative importance index (RII) method on a highway project. Encountering risks anywhere throughout the planning and construction phase is one of the main reasons for the failure of a project. LSTIPs hold risks due to their size and complexity. For the assessment of the risks, the risk factors arising in LSTIPs were obtained from a comprehensive literature analysis as displayed in Table 1.

Table 1. Previous studies undertaken in the identification of risk categories and risk factors in LSTIPs

Risk Categories								
Construction	Management	Financial	Technical	Economic	Legal	Natural & Environmental	Political	Previous study
			√		√	√	√	[10]
√		√	√	√		√	√	[11]
√	√		√		√	√		[12]
	√	√		√	√	√	√	[13]
	√		√	√			√	[14]
√	√	√	√			√		[8]
√	√	√	√		√	√	√	[11]
√			√	√		√	√	[15]
√				√				[16]
√	√							[17]
		√	√			√	√	[18]
				√				[19]
√			√			√	√	[9]
√		√			√		√	[20]
√		√	√	√	√			[21]

3. Research method

A questionnaire survey was adapted and developed from the El-Sayegh study [22] in order to collect demographic information of respondents and to sort risk factors under categories related with LSTIPs. Figure 1 illustrates the process which was followed to identify and assess the risks of LSTIPs in study.

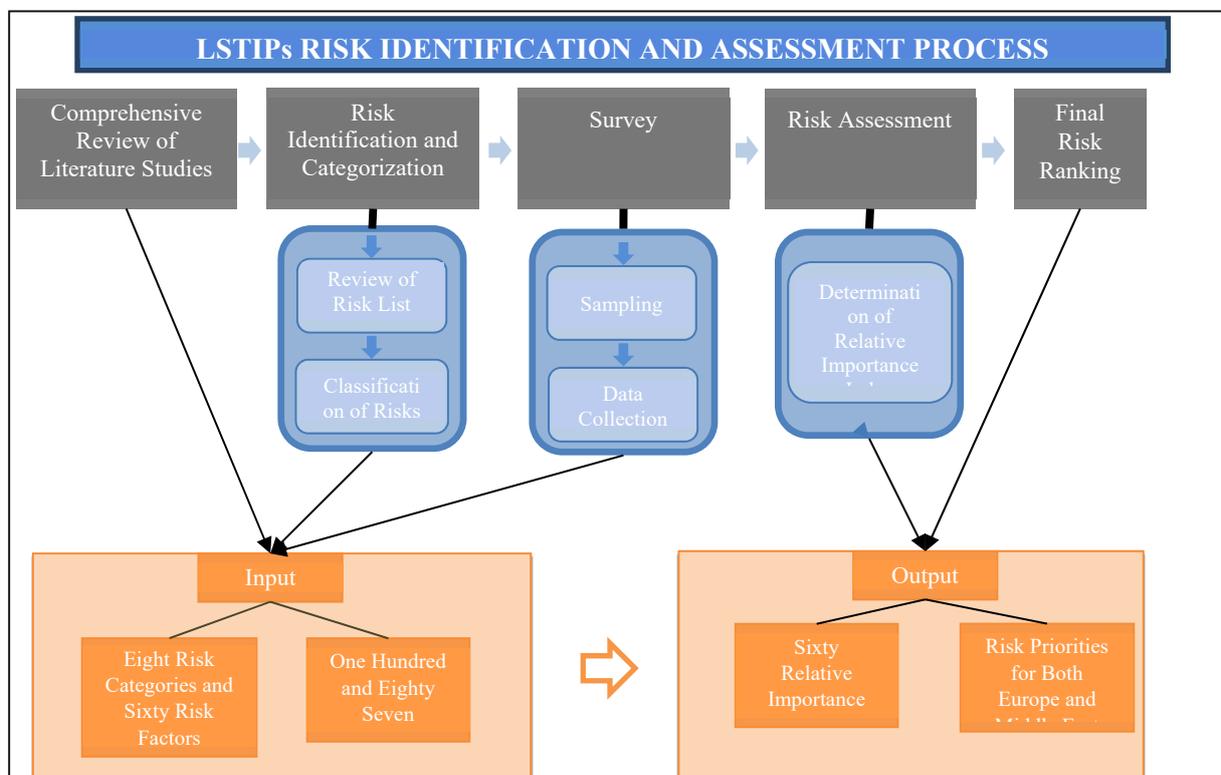


Figure 1. Risk Identification and Assessment Process for LSTIPs in Europe and Middle East

3.1. Sampling

This study focuses on contractor and engineering consulting firms specialized in LSTIPs and located in both Europe and the Middle East. The list consists of 250 international contractor and engineering consulting firms. The sample is exclusive for large-scale firms.

3.2. Data collection

The questionnaire was administered by establishing a connection with a total of 250 large firms which have undertaken European and Middle Eastern projects. By receiving a completed questionnaire from respondents of 187 firms, it is noted that having a high response rate of 74 per cent proved the study to be effective and attention grabbing among participants. The respondents were required to select the degree of importance for each statement on a five-point Likert scale, ranging from 1 (unimportant) to 5 (Extremely important). The first part of the questionnaire aims to gather demographic information about the respondent and the second part aims to obtain the priority orders of sixty factors listed under eight different risk categories. The personnel from the contacted firms hold top management and senior management positions. Therefore, this study confirms the data provided by the participants, supporting the validity of the research aim. Table 2 presents the respondents' background (role, years of experience in LSTIPs); Table 3 displays the respondents' area of experience in LSTIPs (tunnels, bridges, railways, highways and subways) and Table 4 shows the respondents' average project cost (approximate cost of the fulfilled projects).

Table 2. Respondents' Role and Years of Experience in LSTIPs according to Regions

		Respondent's Background			
		Contracting Firm		Engineering Consulting Firm	Total
		Project Manager (40.64%)	Construction Manager (26.73%)	Civil Engineer (32.62%)	
Regions	Europe	42 (22.45%)	21 (11.22%)	35 (18.71%)	98
	Middle East	34 (18.18%)	29 (15.5%)	26 (13.9%)	89
Years of experience for Europe	>20 years	18 (9.62%)	6 (3.21%)	13 (6.94%)	37
	11-20 years	7 (3.74%)	8 (4.27%)	5 (2.67%)	20
	5-10 years	11 (5.87%)	5 (2.67%)	9 (4.81%)	25
	<5 years	6 (3.21%)	2 (1.06%)	8 (4.27%)	16
Years of experience for Middle East	>20 years	14 (7.48%)	12 (6.41%)	6 (3.21%)	32
	11-20 years	8 (4.27%)	7 (3.74%)	8 (4.27%)	23
	5-10 years	5 (2.67%)	6 (3.21%)	9 (4.82%)	20
	<5 years	7 (3.74%)	4 (2.13%)	3 (1.61%)	14

Table 3. Respondents' Area of Experience in LSTIPs according to Regions

Regions	Respondent's Area of Experience in LSTIPs				
	Tunnel (43.78%)	Bridge (34.41%)	Highway (71.05%)	Railway (22.35%)	Subway (15.92%)
	Number	Number	Number	Number	Number
Europe	22 (22.44%)	15 (15.31%)	30 (30.61%)	12 (12.24%)	9 (9.18%)
Middle East	19 (21.34%)	17 (19.1%)	36 (40.44%)	9 (10.11%)	6 (6.74%)

Table 4. Respondents' Average Project Cost according to Regions

US (\$)	Respondent's Average Project Cost	
	Europe (98)	Middle East (89)
>10 billion	13 (13.26%)	11 (12.35%)
5-10 billion	29 (29.59%)	19 (21.34%)
1-5 billion	34 (34.69%)	31 (34.83%)
<1 billion	22 (22.44%)	28 (31.46%)

3.3. Research Findings and Analysis

In this section, in order to determine the priority orders of risks confronted in LSTIPs, participants were asked to express their personal opinions by rating the importance of factors listed under each risk category. The RII method was applied to determine to what extent risk factors and categories affect the performance of projects by receiving opinions of firms and their stakeholders who are involved in European and Middle Eastern LSTIPs as seen in Table 5. RII is computed as [22]:

$$RII = \frac{\sum W}{A \times N} \quad (1)$$

Where: W is the weight given to each factor by the respondents and ranges from 1 to 5,
 A is the highest weight = 5,
 N is the total number of respondents.

4. Discussion of Survey

Change in scope of work, financial strength of client, poor definition of scope and inappropriate contracting, situated respectively under the construction, financial, technical and legal categories, are four common factors in Europe and the Middle East ranked as number one. It is evident that respondents believe these factors have a high impact on LSTIPs with a value of RII 0.83 for Europe and a value of RII 0.81 for the Middle East. The conducted interviews and observations highlight that changes in the scope may occur as projects progress from design to completion stages. Scope alterations generally originate from project managers or design teams. Therefore, a project may fail due to lack of communication and ambiguity in the project [23]. Generally, the lack of funding of project owners or delays in the payment of project services could lead to a postponement or even a stoppage of project work [24]. It is a commonly held view that one of the primary causes of project failure is the poor definition of scope [25]. In the process of a project; this condition emerges as a result of misunderstandings and erroneous actions. For instance, launching structures on the market in a precipitate manner or the lack of designing and planning skills within the firm lead to a poor definition of scope. When construction contracts usually involve more than one party, the omission of details and responsibilities in a contract could bring about claims and disputes among parties during the project period [26]. This matter could freeze the project and be led to court.

The findings for Europe indicate that in addition to the aforementioned factors that rank number one, contractors' poor management ability, resources availability, flood, rigid bureaucracy listed in the management, economic, natural & environmental and political categories also take first place in importance. According to respondents, it can be understood that these factors have a large impact on LSTIPs with a value of RII 0.83 for Europe. The information gathered from interviews and observations state that the most prevalent reason for the failure of contractors is poor management abilities. In accordance to this, the inadequacy of the contractor could cause weak supervision and poor application of procedures associated with company policies [27]. The lack of materials, labour and heavy equipment in the building site create a risk in resource availability which could cause an increase in the current cost of the project [28]. Due to the lack of flood risk assessment methods, huge economic costs arise and

people may be exposed to dangerous circumstances [29]. Thus, flood risk assessment has become an indispensable component in projects. With the incompleteness of procedures and the increment of requirements, the running of a project proceeds slowly. The main reason for this stems from the rigid bureaucracy which affects the development of the construction sector [30].

Table 5. Results of RII for LSTIPs implemented in Europe and the Middle East

LSTIPs Risk Priority						
Category	Risk factors	Europe		Middle East		
		RII	Rank	RII	Rank	
Construction	Change in scope of work	0.83	1	0.81	1	
	Lack of experienced workers	0.73	7	0.72	7	
	Poor coordination among the consultants	0.79	4	0.79	4	
	Faulty construction techniques	0.76	5	0.80	2	
	Cost escalation	0.80	3	0.80	2	
	Inadequate construction planning	0.82	2	0.76	5	
	Low safety awareness	0.74	6	0.74	6	
Management	Labour disputes and strikes	0.73	7	0.74	6	
	Loss of control	0.80	3	0.81	1	
	Improper project feasibility and planning	0.74	6	0.79	4	
	Unrealistic scheduling	0.79	4	0.76	5	
	Poor communications among stakeholders	0.76	5	0.79	4	
	Contractors' poor management ability	0.83	1	0.80	2	
	Rentals	0.73	7	0.72	7	
Financial	Financial strength of client	0.83	1	0.81	1	
	Financial failure of contractor	0.82	2	0.80	2	
	Design variations	0.76	5	0.76	5	
	Incomplete or inaccurate cost estimate	0.79	4	0.79	4	
	Inadequate site information	0.80	3	0.80	2	
	Employment of inexperienced designers	0.80	3	0.80	2	
	Changes to the technology used	0.74	6	0.79	4	
Technical	Insufficient or incorrect design information	0.76	5	0.76	5	
	Shortage of skills or techniques	0.73	7	0.74	6	
	Poor definition of scope	0.83	1	0.81	1	
	Material suitability and accessibility and shortage	0.79	4	0.79	4	
	Inadequate time allocation	0.73	7	0.76	5	
	Inflation	0.73	7	0.74	6	
	Exchange rates fluctuation	0.79	4	0.76	5	
Economic	Increased materials cost	0.82	2	0.81	1	
	Economic crisis	0.74	6	0.79	4	
	Tax rate	0.80	3	0.76	5	
	Resources availability	0.83	1	0.80	2	
	Permits and licenses	0.74	6	0.72	7	
	Conflict in laws	0.76	5	0.76	5	
	Breach of agreements	0.82	2	0.80	2	
Legal	Misinterpretation	0.79	4	0.74	6	
	Inappropriate contracting	0.83	1	0.81	1	
	Nationalism and local protectionism	0.80	3	0.79	4	
	Natural & Environmental	Fire	0.76	5	0.76	5
		Water pollution	0.80	3	0.81	1
		Flood	0.83	1	0.79	4
		Earthquake	0.76	5	0.80	2
Wind (storm)		0.74	6	0.76	5	
Unforeseen adverse site conditions		0.79	4	0.74	6	
Changes of planning		0.76	5	0.79	4	
Political	Unsupportive government policies	0.80	3	0.81	1	
	Rigid bureaucracy	0.83	1	0.80	2	
	Embargoes	0.76	5	0.76	5	
	War and civil disorder	0.82	2	0.74	6	
	Bribery	0.79	4	0.76	5	

Apart from the previously mentioned factors ranking number one for both Europe and the Middle East, the loss of control, increased materials cost, water pollution and unsupportive government policies placed under the management, economic, natural & environmental and political categories are four further factors ranked first for the Middle East. The responses of the participants indicate that these factors have a high impact on LSTIPs with a value of RII 0.81. The data from the interviews and observations reveal that the major causes of the loss of control in projects involve the inadequate cooperation among contractors and other managers, poor organization, transferring the contractor's financial control to the management office and weak communication skills [31]. When contractors undertake a job, they negotiate over a determined total cost considering the material prices of the current year. These details are stated accordingly in the contract. However, if the project exceeds the specified time period, any small tax or increase in inflation will likely reduce the profit [32]. During the implementation of projects gas, oil, isocyanates, solvents, and other kinds of harmful chemicals are used in building sites. If precautions are not taken, these wastes could cause water pollution. Although building sites are cleared up, these types of substances dissolve in the soil when exposed to sunlight, thus contaminates natural water resources [33]. Unsupportive policies, also known as tax and inadequate distribution of funds, applied by the government could not only complicate the implementation of projects but also bring them to a stopping point [34].

5. Conceptual Framework of Risk Assessment of LSTIPs for Planning Phase

This study has generated outcomes which will inform managers about the most common type of risks confronted in LSTIPs and has also propounded a reference tool for risk assessment. Risk identification in the planning phase is a crucial element for the fate and accomplishment of a project. The risk factors and priority orders achieved in this study could be utilized effectively to reduce, deflect or eliminate risks which could arise during the construction phase. Risk responses ensure the successful accomplishment of the project. Figure 2 clearly demonstrates the conceptual framework of risk assessment of LSTIPs used to achieve favourable outcomes. With responses taken, the project could be fulfilled with more profit in the financial category, more safety in the technical category and less pollution in the environmental category. In addition to this, by taking measures, coordination could improve in project work in the management category, conflicts and oppositions may lessen in the legal and political category and the quality of workmanship could increase in the construction category. The development of supportive models in LSTIPs can facilitate and enable the enhancement of construction projects. Moreover, this research could grasp attention and be an area of consideration for stakeholders and firms. A guideline created from the results of this study could foster pertinent projects.

6. Conclusions

This paper presents a process for identifying and assessing risk factors under categories which could emerge in European and Middle Eastern LSTIPs. At the same time, it provides a conceptual framework that guides firms in taking responses to risks in the construction phase. To develop the conceptual framework, risk categories and their factors were derived from an extensive literature review. Based on the degrees of importance attained from the conducted questionnaire, the obtained factors were assessed with the use of RII method. In the last stage of the process, the RII results were ranked in categories separately for each region in order to determine the priority orders of risk factors. According to the findings, the LSTIPs factors "change in scope of work", "financial strength of client", "poor definition of scope", and "inappropriate contracting" have the highest level of RII for both Europe and the Middle East. The change of scope, which generally occurs during the planning stage or seldom in the construction stage, increases the cost of the project. On the other hand, the weak financial power of the project's sponsor could prevent the advancement of the project or even terminate it. A poor definition of the scope may arise from constructing projects in a cursory manner. Additionally, when all responsibilities and conditions are not clarified in the contract, any of the parties in the project could take legal action and bring the project to a standstill. The factors respectively "Contractors' poor management ability", "Resources availability", "Flood" and "Rigid bureaucracy" hold the highest level

of RII for Europe whereas the factors respectively “Loss of control”, “Increased materials cost”, “Water pollution” and “Unsupportive government policies” hold the topmost level of RII for the Middle East.

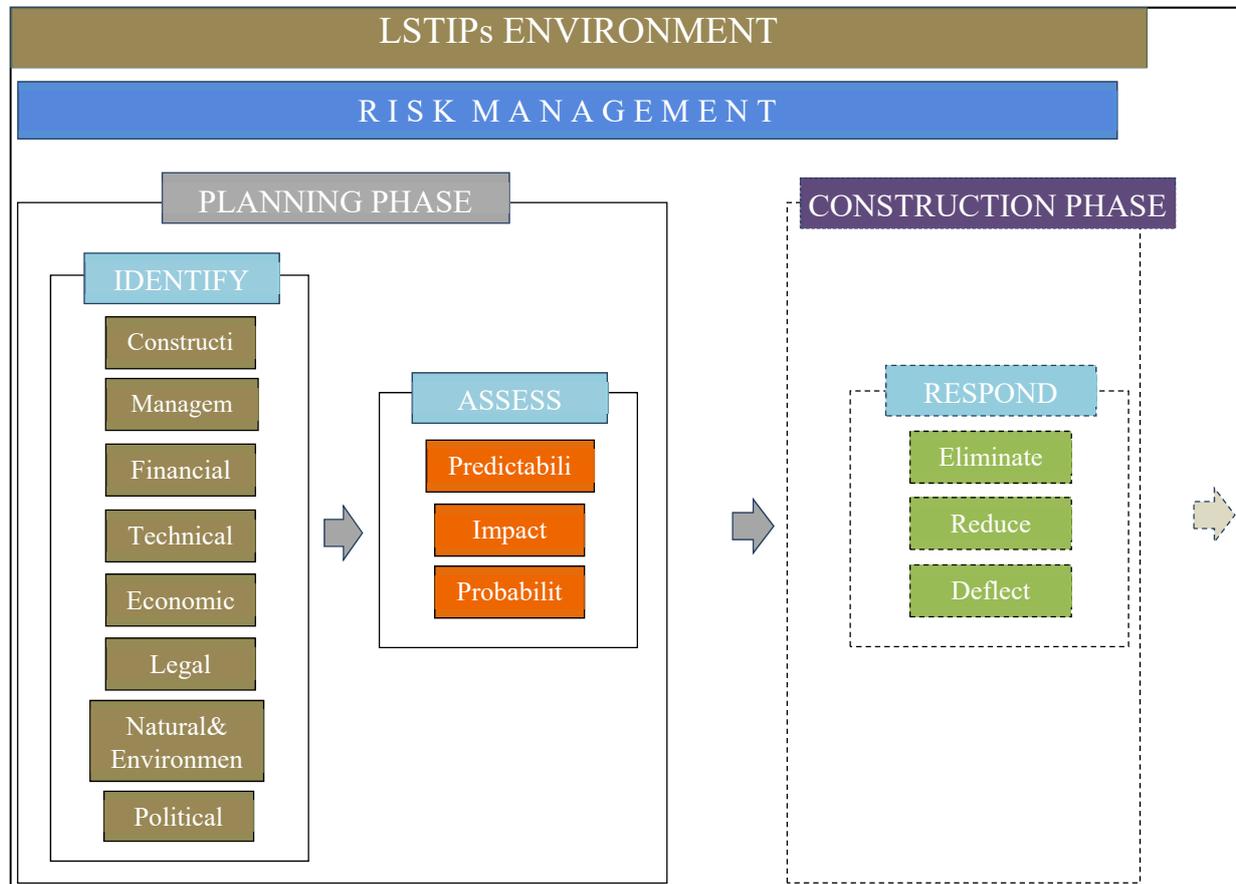


Figure 2. Conceptual Framework of Risk Assessment of LSTIPs for Planning Phase

The results clearly show that the risk priority orders in Europe and in the Middle East differ in terms of the experiences of managers, economical power of the regions, the geographical locations and dissimilar regimes. Furthermore, the risk factors and priority orders could be utilized or integrated in other projects in the global world. This study also raises awareness of firms and those pertinent to LSTIPs on the benefits of risk assessment and stimulates upcoming projects. As a conclusion, this study emphasizes the possible risks in European and Middle Eastern LSTIPs and promotes the process of identification and assessment in the planning stage.

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