A Knowledge-based Model for the Stakeholders' Risk Assessment in 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 the successful completion 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) are developed structures that emerged from the essential necessity of fast-paced and convenient transportation in gradually growing populations. LSTIPs, technologically equipped projects, meet the essential needs of the recent era but also bring about numerous risks such as financial, technical, managerial, political, economical, 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.

Regarding the risks that could be confronted in European and Middle Eastern LSTIPs, this study aims to investigate and determine the possible risks in order of priority for each region by means of an Analytical Network Process (ANP) method. A comprehensive literature review was conducted to determine the risks that were thereafter synthesized in collaboration with pertinent experts. The priority orders were obtained separately for Europe and the Middle East, and comparisons were made between these regions. The results in the study highlight that Europe and the Middle East share both common and distinctive risk factors in the orders of priority. "The financial strength of the client" listed in the financial category for Europe and the Middle East received a priority value of 13.37% and 11.54%, respectively, clearly ranked as the foremost common risk factor for the two regions. However, salient differences were noted in the second leading risk categories for Europe and the Middle East, namely, the findings revealed that the "change in scope of work" risk factor under the construction category has a priority value of 5.48% for Europe and the "water pollution" risk factor under the natural and environmental category has a priority value of 4.55% for the Middle East. To further support the priority orders achieved in this study, two different case studies were conducted. This study also 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. This study also incorporates a developed knowledge-based tool that is an aid to rapid and efficient risk identification and decision making in the planning phase of LSTIPs operated by firms in Europe and the Middle East. This knowledge-based tool was created by using the data attained from the firms as well as the risk factors' priority orders obtained from the ANP model to deploy the logical if-then rules in order to convert them to Exsys corvid shell. In addition to highly contributing to the LSTIPs in Europe and the Middle East, it is believed that the priority orders and the LSTIPs risk identification and decision supporting (RiDECS) tool achieved in this study could be used as a guideline for identifying and sequencing risks in the planning stages of similar projects conducted in various countries. Moreover, future related studies could be juxtaposed with the results of this study to analyze the alterations of priority orders that will have occurred in the course of time.

Keywords: large-scale; transport; infrastructure projects; ANP; Europe; Middle East; knowledge-based; RiDECS; Tool

ÖZ

Bir projenin planlama aşamasında risklerin tanımlanması ve etki değerlerinin düzenlenmesi, günümüzün çeşitli inşaat projelerinin ana bir temeli haline gelmiştir. Sağlam ve iyi planlanmış projelere rağmen, olası riskler önceden tespit edilip değerlendirilmezse, projenin herhangi bir aşamasında beklenmeyen problemler ortaya çıkacaktır. Bu nedenle, bu süreç, bir projenin problemlerini en aza indirmenin yanı sıra, başarının arttırılmasında da bir ihtiyaç haline gelmiştir. Büyük ölçekli ulaştırma altyapısı projeleri (BÖUAP), giderek artan nüfus içinde hızlı tempolu ve rahat ulaşımın temel gerekliliğinden ortaya çıkan yapılar geliştirilmektedir. Teknolojik olarak donanımlı projeler olan BÖUAP'ler, son dönemin temel ihtiyaçlarını karşılarken, aynı zamanda finansal, teknik, yönetimsel, politik, ekonomik, doğal ya da yasal olmak üzere birçok risk beraberinde getirmektedir. Bu nedenle, BÖUAP'lerin planlama ve inşaat aşamasında bu tür risklere maruz kalmak, projenin kaderinde olumsuz sonuçlara yol açabilir.

Avrupa ve Orta Doğu BÖUAP'lerinde karşılaşılabilecek risklere ilişkin olarak, bu çalışma her bir bölge için bir öncelikli olarak bu olası riskleri bir Analitik Ağ Süreci (AAS) yöntemi ile listelemeyi amaçlamaktadır. Daha sonra ilgili uzmanlarla işbirliği içinde sentezlenen riskleri belirlemek için kapsamlı bir literatür taraması yapıldı. Öncelikli sıraları Avrupa ve Orta Doğu için ayrı ayrı elde edilmiş ve bu bölgeler arasında karşılaştırmalar yapılmıştır. Çalışmadaki sonuçlar, Avrupa ve Orta Doğu'nun öncelik sıralarında hem ortak hem de ayırt edici risk faktörlerini paylaştığının altını çizmektedir. Avrupa ve Orta Doğu için Mali kategoride listelenen "müşterinin mali gücü", sırasıyla %13.37 ve %11.54'lük bir öncelik değeri aldı ve iki

bölge için en önemli ortak risk faktörü olarak belirlendi. Bununla birlikte, Avrupa ve Orta Doğu için ikinci en önemli risk kategorilerinde göze çarpan farklılıklar göze çarpmaktadır; diğer bir ifadeyle, bulgular, inşaat kategorisindeki “iş kapsamındaki değişiklik” risk faktörünün Avrupa için % 5.48, Doğal ve çevresel kategoride “su kirliliği” risk faktörü, Orta Doğu için % 4.55'lik bir öncelik değerine sahiptir. Bu çalışmada elde edilen öncelik sıralarını daha fazla desteklemek için iki farklı örnek olay incelemesi yapılmıştır. Bu çalışma aynı zamanda planlama aşaması için bir yol oluşturan ve risk listelerini ve inşaat aşamasını güçlendiren öncelik sırasını sunan bir kavramsal çerçeveyi geliştirmeyi amaçlamaktadır. Bu çalışma aynı zamanda Avrupa ve Orta Doğu'daki firmalar tarafından işletilen BÖUAP'lerin planlama aşamasında hızlı ve etkin risk belirleme ve karar verme sürecine yardımcı olan gelişmiş bilgi tabanlı bir aracı içermektedir. Bu bilgi tabanlı araç, firmalardan elde edilen veriler ve AAS modelinden elde edilen öncelik sırasına göre risk faktörlerinin, Exsys corvid kabuğuna dönüştürmek için mantıksal if - then kuralları kullanmasıyla oluşturulmuştur. Avrupa ve Orta Doğu'daki BÖUAP'lere büyük ölçüde katkıda bulunmanın yanı sıra, bu çalışmada elde edilen öncelik sıraları ve BÖUAP'lerin risk belirleme ve karar destek (RBKD) aracının, planlama aşamalarındaki risklerin belirlenmesi ve sıraya konulması için bir kılavuz olarak çeşitli ülkelerde benzer projelerin yürütülmesinde kullanılabileceği düşünülmektedir. Ayrıca, zamanla ortaya çıkacak öncelikli sıralarının değişikliklerini analiz etmek için bu çalışmanın sonuçları ile gelecekteki ilgili çalışmalar yan yana getirilebilir.

Anahtar Kelimeler: büyük ölçekli; ulaştırma; altyapı projeleri; AAS; avrupa; orta Doğu; bilgi tabanlı; RBKD; araç

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ANP	Analytical Network Process
MCDM	Multi-Criteria Decision-Making
LSTIPs	Large–scale Transport Infrastructure Projects
TEN-T	Trans-European Transport Networks
GCC	Gulf Cooperation Council
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
ELECTRE	Elimination and Choice Translating Reality
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluation
RII	Relative Importance Index
NGT	Nominal Group Technique
CHF	Swiss franc
UK	United Kingdom
EPC	Enginnering Procurement Construction
RBS	Risk Breakdown Structure

Chapter 1

INTRODUCTION

1.1 Background

Over the past two decades, Large-Scale Transport Infrastructure Projects (LSTIPs) have come into prominence in the construction industry and have gained significant amount of attention and interest in the research fields among European and Middle East countries. Evidence suggests that LSTIPs have encountered numerous risks because of the vast amount of time allocated to the planning and implementation phases, the complicated interactions among diverse stakeholders and the variations between the practised economical and technical procedures (UK DfT, 2011).

Correspondingly, the high risks and costs of large-scale infrastructure projects have become a major concern around Europe and the Middle East. The Trans-European Transport Network (TEN-T) programme has provided 30% of the monetary support to the transport infrastructure projects of the European region. Since the beginning of the project, many airports, roads and railways have been financed. According to EC delegation (EC Delegation, 2011), the estimated cost in completing the transport infrastructure projects by 2020 is approximately €500 billion. Similarly, the Gulf Cooperation Council (GCC) in the Middle East has made developments by expanding the number of transport infrastructure projects to solve issues regarding population growth, urbanization and traffic congestion. From the second half of 2017, it was estimated that the total cost of road, bridge and tunnel projects would cost $140,645 million and that the railway system projects would cost $240,143 million (Venture O, 2017).

Many studies have been conducted regarding the risks in construction projects. Several research studies have given primary focus to stakeholders' risk management approaches in large-scale projects (Tah and Carr, 2001; Mok et al., 2014). Furthermore, research has been conducted on decision-making methods in risk assessment (Jannadi and Almishari, 2003; Li and Liao, 2004; Zavadskas, 2010). Recently, ANP has become one of the most widely used methods on risk assessment to assist Multi-criteria Decision-Making (MCDM) issues in construction projects.

Although the ANP method has been applied in the construction sector among Europe and the Middle East, AHP, the previously developed version, is given further priority. However, the AHP is a system consisting of a unidirectional comparison that is generally preferred for sorting alternatives according to criteria and for their selections. Therefore, researchers have observed that because the ANP method is a system that makes bidirectional comparisons within itself and provides feedback, it further supports MCDM. Additionally, having the distinguishable feature to consider feedback among criteria and inner-and-outer dependencies that are distinct from other MCDM methods (TOPSIS [Technique for Order Preference by Similarity to Ideal Solution], ELECTRE [Elimination and Choice Translating Reality], and PROMETHEE [Preference Ranking Organization Method for Enrichment Evaluation]), the ANP method enables more efficient and realistic decision making as well as good traceability of the decision and the quality assurance given by the consistency indices (Omurbek and Simsek, 2014). Furthermore, it was revealed in the same study that no single investigation exists in this focus area covering both Europe and the Middle East regions.

The main aim of this study is to investigate and determine the risks that could come into existence during the planning and construction phase of LSTIPs in both regions, their priority orders and the characteristics of these projects. Boundaries of current computerized project-control systems can handle and manage construction projects considerably with the application of different types of computer-based software known as knowledge-based system. Knowledge-based softwares are prevalent computer systems that are applied to overcome numerous complications. However, LSTIPs have confronted different types of risks during construction processes that are constantly increasing in time, thus, it is obvious that recent risk identification and decision support tools and techniques are not sufficient to prevent or eliminate these risks in the planning phase. In addition to this, accessing experts to gather information in their area of expertise is a troublesome and time consuming process, especially if communication lacks between the expert and engineer. Therefore, in the light of the data attained, this study also aims to develop a knowledge-based risk identification and decision support tool for the planning stage of forthcoming LSTIPs in both regions with the use of EXSYS CORVID shell.

With the obtained priority orders and the recommended tool, this study also intends to provide a basis for managers and companies involved in forthcoming European and Middle Eastern projects.

1.2 Scope and Objectives

The aim of this thesis is to determine the priority orders of risks by investigating which risks could occur in the planning and construction stages of large scale transport infrastructure projects. Furthermore, the obtained priority orders could be utilized as a database for managers and firms occupied in the planning stage of forthcoming European and Middle Eastern projects. At the same time, a tool is put forward aiming to encourage more effective and rapid risk identification and decision making in the planning phases of future LSTIPs in Europe and the Middle East. The objectives of this study are to:

- Identify the risks that could occur in large-scale transport infrastructure projects in the European and Middle Eastern regions;
- Determine the significances of risks that could occur in European and Middle Eastern LSTIPs;
- Develop an ANP model for LSTIPs with the use of obtained risk factors;
- Sort the risk priorities via using super decision software program;
- Compare risk categories and pinpoint the weaknesses of Europe and the Middle East against risk types;
- Test the consistency of the obtained priority orders by comparing them with the results of two different case studies;
- Propose the orders of risk categories and factors as a reference guide for forthcoming projects operating in Europe and the Middle East;
- Determine the applicability of the developed ANP model;
- Present a knowledge-based risk identification and decision support tool for Europe and the Middle East in the LSTIPs' planning phase;
- Create a conceptual framework for forthcoming projects.

1.3 Works Undertaken

The following actions were carried out in order to achieve the objectives of this thesis:

- Risk factors that could possibly emerge in LSTIPs were identified by means of an extensive literature review;
- The significances of risk factors were detected in LSTIPs operated by firms in Europe and the Middle East by conducting a closed-ended questionnaire via email;
- The ANP model was formed by using NGT and CNM with experienced individuals in the area of LSTIPs to synthesize risk factors;
- A closed-ended pairwise comparison questionnaire was administered to experienced construction managers, project managers and civil engineers in Europe and the Middle East via email;
- The priority orders of risks were determined with the implementation of the ANP created in the Super Decisions Software;
- The priority orders of risk factors in both regions were compared to identify their differences in terms of priority orders as well as their weaknesses relative to one another;
- To test the consistency of the obtained priority orders in Europe and the Middle East, face-to-face meetings were held with two different firms and case studies were carried out accordingly;
- A reference table was created to be used by two of the regions in future LSTIPs;
- The applicability of the proposed ANP model in two of the regions was tested with a closed-ended questionnaire;

- A knowledge-based risk identification and decision supporting tool was put forward for the planning stage of future LSTIPs in two of the regions;
- A conceptual framework was developed to guide firms in managing risks more effectively in the planning stage of future LSTIPs.

1.4 Methodology

Methodology is regarded as a planned and systematic process followed to solve different problems within a particular area of study. It is a pathway that indicates how research could be carried out. Collis and Hussey (2014) describe methodology as a set of general principles and views that manage how, where, what and why questions in the collection and analysis of data. Being knowledgeable about different forms of research methods as well as the accurate framework, convenience, consequences and efficiency of methodological procedures is essential when conducting research. Methodology is a matter of investigating, describing, speculating, exploring and explaining throughout the process (Rajasekar et al., 2006).

The fundamental research methods applied to achieve the objectives of this study are: comprehensive review of literature, the identification and determination of the significances of risk factors, development and implementation of ANP model, production of case studies to check consistency of the results, development of a conceptual framework and the analysis of the applicability of the ANP model results, and the development of a tool for the risk identification and decision supporting in LSTIPs. The practiced methods in this study are discussed briefly below.

1.4.1 The Literature Review

The literature was reviewed to outline previous research in the area of large-scale transport infrastructure projects. The literature review is based on the emergence of the large-scale construction sector, the theoretical background of LSTIPs and conducted risk assessments, the risk types which could possibly occur and the ANP method, one of the MCDM methods, pertinent research studies, and knowledge-based systems. The risk factors and categories obtained from the review were used in the analysis of RII and ANP, and in the development of the knowledge-based model.

1.4.2 Determination of Significances of Risk Factors

The risk factors identified from the literature review were categorized. The obtained risk factors and categories were utilized into a questionnaire that evaluated the significances of factors in LSTIPs by means of experienced firms. In addition to this, with the results of the questionnaire, the RII were assessed to do rankings. In conclusion, the significances of risks factors were determined and discussed for both of the regions.

1.4.3 Development and Implementation of ANP Model

After the significances of risk factors were assessed, they were synthesized with the use of NGT and CNM by experienced individuals. Besides this, a risk breakdown structure that presents the relationship between factors and categories were created to prevent misinterpretation of information. Based on the structure, Super Decisions Software was used to develop an ANP model. To apply the ANP model, project managers, construction managers and civil engineers experienced in the areas of the factors listed under each risk category made pairwise comparisons. The consistency ratios of comparisons were checked accordingly. With the results of the comparisons, Super Decisions Software was used to obtain limit super matrix, in other words, to determine the priority orders of risk factors. Finally, the results of both regions were compared to one another.

1.4.4 Conducting Case Studies

To measure the consistency of the obtained priority orders, a construction project from each region was selected and two different case studies were carried out accordingly. Information regarding the backgrounds of firms, the project, the risks arising in the project and the priority orders of risks pertaining to firms were gathered for the case studies.

1.4.5 Development of Conceptual Framework and Testing the Applicability of the ANP Model and Results, and Proposing a Risk Identification and Decision Supporting Tool

A conceptual framework was developed to guide firms in using the assessment results more efficiently in forthcoming LSTIPs and to manage the risks in the planning phase more effectively. By considering the structure of the proposed ANP model and its results, the applicability was tested via questionnaire.

In addition to this, in order to use the risk factors' priority orders obtained from the ANP model as well as data gathered from firms more efficiently and rapidly, a knowledge-based risk identification and decision supporting (RiDECS) tool was developed and implemented for the planning stage of LSTIPs.

1.5 Achievements

The achievements of this thesis are stated below and are aligned to the objectives and works undertaken.

- The risks occurring in LSTIPs were identified for both Europe and the Middle East through an extensive literature review;

- The significances of the risks that are confronted in LSTIPs both in Europe and the Middle East were obtained via closed-ended questionnaire by relative importance index;
- An ANP model was developed to sort priority orders of the risk factors for both regions;
- The pairwise comparisons of risk factors were attained with experienced project managers, construction managers and civil engineers via closed-ended questionnaire;
- Priority orders of the risk factors were obtained by implementing a developed ANP model for each region in Superdecisionsoftware;
- Differences of risk factors' priority orders as well as their weaknesses were detected for both regions by means of comparison;
- The priority orders' results were evaluated by conducting two different case studies which indicated the consistency among results;
- A table consisting of risk factors' priority orders table was created as a reference tool for the planning stage forthcoming projects in both Europe and the Middle East;
- The proposed model was found to be applicable based on the results of a closed-ended questionnaire;
- With the use of obtained priority orders and data collected from firms, a knowledge-based risk identification and decision supporting tool was introduced for the planning stage of future LSTIPs;
- A conceptual framework was composed to guide firms manage risks more effectively in the planning phase.

1.6 Guide to Thesis

This thesis consists of six chapters. In chapter two, a literature review is undertaken on LSTIPs. The emergence of large-scale in the construction industry, LSTIPs' background and the risk assessment in LSTIPs are discussed. In addition to this, multicriteria decision making methods, ANP method and the previous studies conducted via ANP method are described.

The third chapter discusses the methodology applied in this thesis. It explains the identification of risk factors, the application of relative importance method, the development and implementation of ANP method, case studies, the development of the conceptual framework and lastly the applicability of the proposed ANP model and its results.

The forth chapter presents the analysis and results of the study. It states a profile of respondents as well as the analysis and discussion of relative importance index results. In addition to this, this chapter also provides the readers an analysis of ANP which covers respondents demographic profile, area of experience, average project cost, similarities of given responses, a group meeting, development of risk breakdown structure, the process of obtaining limit super matrix, comparison of results for both regions and the results of conducted case studies.

Chapter five describes and provides the creation of a conceptual framework for LSTIPs in the planning phase. The fifth chapter also presents the results of the applicability of an ANP model. Moreover, the development and implementation of a knowledge-based system that will be used as a RiDECS tool in the planning phase of LSTIPs is explained.

The sixth chapter highlights the main conclusions drawn from this study and states recommendations for future studies. Appendix part displays the questionnaire forms used in this thesis as well as several analysis tables.

Chapter 2

LARGE-SCALE TRANSPORT INFRASTRUCTURE PROJECTS

2.1 Large-scale Projects in the Construction Industry

The process of industrialization has not only given rise to economic impacts but has also made important developments in social structure and physical area. In cities where the economic system was built on industry, industrial zones covered a large part of the city until the industries moved to the outskirts of the city or other areas where manufacturing was cost-effective. Following this, unemployment rates increased, old city centres, port zones, and industrial structures were abandoned, portraying a poor image of cities and reducing public revenues. To attract new investments during this period, renewal actions supported by the new ideas of neoliberalism commenced in the abandoned areas of the city. At this point, large-scale projects began to be designed, aiming to gain investment with the contribution of the private sector as well as to bring a new and powerful image to the cities, especially in high-profile areas such as urban centres or coastal settlements, (Kennedy et al., 2011).

Large infrastructure projects, also referred to as Mega Projects, are of extremely high costs ranging from a hundred million to seven billion dollars (Flyvbjerg, 2005). These projects range from urban projects to other types such as high-speed train lines, airports, ports, highways, hospitals, dams and wind fields. Since large-scale projects undergo a comprehensive research, design and construction period, any miscalculations in the costs could result in a great burden on investors as well as the economy of the country. These cost overruns, seen in nine tenths of the projects, could sometimes lead to the stoppage or termination of the projects. Although cost overruns up to 50% is regarded normal, cost overruns that highly exceed this rate are seen frequently (Cantarelli et al., 2013). For instance, the Manch tunnel, known as Europe's longest underwater railway tunnel that connects Britain and France, was completed with an 80% cost overrun and similarly the Hamburg Bridge was finalized with 175% cost overrun (Aljohina et al., 2017). In addition to this, the Denver international airport was built with a 200% cost overrun (Flyvbjerg et al., 2003) and the Suez Canal was constructed with a 1900% cost overrun (Barinov, 2007).

Consequently, because such projects are expensive, the need for governmental support or public-private partnership is put forward. Moreover, these kinds of high cost projects have lengthy time intervals which could bring along numerous risks.

In this chapter, a literature review is carried out on LSTIPs including the background of LSTIPs, risk assessment in LSTIPs and the types of risk in LSTIPs. Furthermore, literature is also reviewed on the MCDM and ANP method. This chapter also provides a review of the literature on a decision support system and an expert system.

2.2 Theoretical Background

2.2.1 Large-scale Transport Infrastructure Projects

It is evident that there has been a gradual increase in the number of LSTIPs conducted by European and Middle Eastern countries in the past twenty years. This observation highlights the significance and necessity of transportation for developed and populous countries. Regarding the literature, the most common type of transport infrastructure projects that have been implemented recently involve highways, railways, underground stations, bridges and tunnels. Considering the importance of transportation in Europe, the construction of the Gotthard Base Tunnel through the Alps in Switzerland in Figure 1 that occurred from year 2010 to 2016 had been determined to have an initial cost of 6.323 billion CHF; however, it was completed with a total cost of 9.561 billion CHF (Masset and Loew, 2013). The tunnel occupies a length of approximately 57.09 km which can be seen in Figure 1.

Figure 1: Gotthard Base Tunnel through Alps in Switzerland (Alptransit, 2016)

The United Kingdom, another country in the heart of Europe that is home to various European countries' citizens and receives millions of visitors per year, holds LSTIPs projects that date back to the 19th century. With the implementation of the Victoria

Line underground project in 1967 and the construction of the orbital motorway named “M25” between 1973 and 1986, it is obvious that emphasis has been placed on LSTIPs from a distant past (Travers, 2009). Moreover, the importance given to transportation infrastructure by the UK government is apparent from the “Crossrail” rail rapid transit line, at 118 km in length, which was extended a further 42 km with the construction of the “Elizabeth line” rail rapid transit in Figure 2 at an additional cost of approximately £14.6 billion (Black, 2016).

Figure 2: Rail System installation of Elizabeth line in the UK (Tucker, 2016)

The aforementioned projects are being constantly innovated and enhanced, reflecting the expanding and developing UK economy.

A significant element of Europe’s transport network is the longest automated metro line in Spain named “Barcelona metro line 9” in Figure 3 that began construction in 2002 and was opened for passenger service in 2010. The metro line has length of 47.8 km and a cost of €6.5 billion (Fuente et al., 2014).

Figure 3: Barcelona Metro Line 9 (Fuente et al., 2014)

A recent project that the French government has undertaken (2014) is the rapid transit railway network named “Grand Paris Express”, which is 160 km in length and worth €32 billion. The completion of the project is expected by 2025 (Enright, 2012). A notable example of Omega transportation infrastructure projects in Europe includes the large Netherlands rail line in 125 km length named “HSL-Zuid” that was finalized in 2009 and cost 9.79 billion dollars (Omega, 2010). Similarly, in 2017, Turkey, another European country, has built the Eurasia tunnel with a total length of 14.6 kilometres and a cost of 1.2 billion dollars in Figure 4 as well as the Yavuz Sultan Selim Bridge of 115 kilometres length at a cost of 3 billion dollars in Figure 5 (Yusufoğlu, 2017).

Figure 4: Eurasia Tunnel in Turkey (Istanbul Metropolitan Municipality, 2016)

Figure 5: Yavuz Sultan Selim Bridge in Turkey (Istanbul Metropolitan Municipality, 2016)

The significance of LSTIPs in the Middle East is clearly observable from the fulfilled number of projects. For example, in Dubai, an economically advanced country in the Middle East, the Dubai metro light rail project was planned in 2009, beginning with the construction of the 53-kilometre-long “red line” worth £1.5 billion, followed and completed by the construction of the 24-kilometre-long “green line” in 2010 at a cost of £800 million (Smith and Hendy 2009). Another significant transport infrastructure project in the Middle East, the Haramain High Speed Rail, links Mecca-Medina in Saudi Arabia; its construction started in 2009, and it is scheduled to open to public in the beginning of 2018 in Figure 6 (Lowe and Altrairi, 2013).

Figure 6: Haramain High Speed Rail in Saudi Arabia (Ofluoglu, 2013)

Consequently, it is apparent that the implementation of LSTIPs to date has facilitated transportation and has made a substantial contribution to the European and Middle East economies. However, LSTIPs have high costs and lengthy construction periods. Thus, it is inevitable to avoid any issues throughout this process that indirectly result in prolonged project duration and increased costs.

2.2.2 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 including Abdollahzadeh and Rastgoo (2015) who used fault tree and event tree analysis methods based on fuzzy logic to assess risks in a bridge project, the Vishwakarma et al. (2016) study which imposed the relative importance index (RII) method on a highway project as demonstrated in Table 1.

Table 1: Relative importance index highway risk factors results (Vishwakarma et al., 2016)

Risk Category	Risk No.	Risks	RII	Rank
Construction	R1	Machineries	0.692307	16
	R2	Delay due to rain or other causes	0.665384	23
	R3	Uncertain construction market conditions	0.642307	28
	R4	Contractor productivity issues	0.723076	11
	R5	Time	0.765384	2
Design	R6	Development around road analysis	0.615384	30
	R7	Uncertainty in horizontal alignment	0.615384	30
	R8	Uncertainty in access requirements	0.680769	17
	R9	Uncertain indirect costs: design, construction, project management	0.696153	15
	R10	Design errors and omissions	0.711538	12
	R11	Consideration of improper basic parameters	0.653846	24
Topography	R12	Construction in hilly region	0.742307	6
	R13	Uncertainty in landscaping activities	0.673076	21
Political	R14	Issues related to obtaining Railway Permits	0.765384	2
	R15	Issues related to obtaining Govt. Permits	0.734615	9
	R16	Other Political or external issues	0.700000	14
	R17	Change in policies	0.669230	22
Land acquisition	R18	Uncertain land acquisition cost	0.753846	5
	R19	Uncertain land acquisition schedule	0.711538	12
	R20	Change in policies	0.642307	28
Environmental	R21	Natural obstruction: hills, rivers, trees	0.653846	24
	R22	EIA Required	0.607692	33
Organizational	R23	Skilled Labour	0.603846	34
	R24	Knowledge level of lead group	0.592307	35
Accidental	R25	Unanticipated damage during construction	0.742307	6
Utilities	R26	Utilities not relocated on time	0.726923	10
	R27	Fuel: availability, price	0.615384	30
	R28	Electricity	0.646153	27
Minerals	R29	Mineral mining issues	0.676923	18
	R30	Cost of minerals	0.676923	18
Law and order	R31	Local disturbances	0.757692	4
Climatic condition	R32	Unforeseen climatic conditions	0.653846	24
Others	R33	Quality: construction, product	0.676923	18
	R34	Funds/Money	0.769230	1
	R35	Emotional issues	0.588461	36
	R36	Heritage issues	0.742307	6

Ghosh and Jintanapakanont (2004) applied the factor analysis approach in an underground railway project to assess critical risk factors as illustrated in Table 2.

Table 2: Importance index of critical risk factors of railway project (Ghosh and Jintanapakanont, 2004)

Rank	Factor	Importance Index
1	Delay risk (F9)	79.00
2	Financial and economic risk (F1)	73.94
3	Subcontractors related risk (F3)	72.91
4	Contractual and legal risk (F2)	72.81
5	Design risk (F6)	72.67
6	Force majeure risk (F7)	68.38
7	Safety and social risk (F5)	68.33
8	Physical risk (F8)	65.33
9	Operational risk (F4)	62.50

The El-sayegh and Mansour (2015) research study implemented the RII in Risk Assessment and Allocation in Highway Construction Projects as displayed in Table 3.

Table 3: Risk assessment and allocation in Highway construction projects (El-sayegh and Mansour, 2015)

		Probability		Impact		Priority
Risk	Description	Level	RII	Level	RII	RII
1	Owner changes	Moderate	2.78	Moderate	3.41	10.31
2	Quality and integrity of design	Moderate	3.20	High	3.78	12.90
3	Material, labor, and equipment resourcing	Moderate	3.14	Moderate	3.47	11.33
4	Inefficient planning	Moderate	3.35	High	3.86	13.41
5	Delays in preparation of submittals	Moderate	2.98	Moderate	3.18	10.02
6	Delays in the approvals of submittals	Moderate	3.35	High	3.57	12.57
7	Poor coordination	Moderate	3.20	High	3.65	12.20
8	Insufficient technology, skills, or techniques	Moderate	2.73	Moderate	3.29	9.67
9	Delays in obtaining no object certificates (NOCs) from authorities	Moderate	3.22	High	3.67	12.41
10	Insufficient right of way	Moderate	2.82	Moderate	3.37	10.55
11	Delays in expropriations	Moderate	3.29	High	3.57	12.53
12	Existing traffic	Moderate	3.08	Moderate	3.26	11.02
13	Unexpected underground utilities	Moderate	3.31	High	3.77	13.00
14	Archeological finds	Low	1.96	Moderate	3.00	6.78
15	Force majeure	Low	2.12	High	3.53	7.71
16	Unforeseen soil conditions	Moderate	2.73	Moderate	3.31	10.00
17	Inadequate safety measures	Moderate	3.06	High	3.80	12.04
18	Feasibility of construction methods	Moderate	2.67	Moderate	3.14	8.98
19	Inadequate construction quality	Moderate	2.92	High	3.59	11.12
20	Delay in payments	Moderate	3.06	High	3.53	11.45
21	Inadequate claim administration	Moderate	2.94	Moderate	3.18	10.00
22	Poorly tailored contract forms	Moderate	2.78	Moderate	3.35	9.94
23	Third-party liability	Moderate	2.61	Moderate	2.94	8.22
24	Conflict in contract documents	Moderate	2.84	Moderate	3.04	9.22
25	Government relations	Low	2.43	Moderate	2.98	8.08
26	Threat of war	Low	1.82	Moderate	3.33	6.53
27	Changes in rules and regulations	Low	2.06	Moderate	2.78	6.49
28	Adverse weather conditions	Low	2.41	Moderate	2.82	7.65
29	Site contamination	Low	2.08	Moderate	2.94	6.49
30	Perceived environmental impacts of projects	Low	2.45	Moderate	2.86	7.55
31	Criminal acts	Low	1.71	Moderate	2.78	5.41
32	Cultural differences	Low	2.18	Low	2.39	5.77
33	Bribes	Low	2.22	Moderate	2.96	7.14

Wang et al. (2015) used AHP to assess risks for a cross-sea route tunnel project. The results can be clearly seen in Table 4.

Table 4: AHP Risk Assessment in a Cross-sea Route Tunnel Project (Wang et al., 2015)

		Risk level and probability								
Risk factor	Weight	1	2	3	4	5	6	7	8	9
A3 Decision-making behavior risks	0.067	0.08	0.1	0.22	0.2	0.19	0.09	0.07	0.03	0.03
B9 Decision makers ability	0.400	0.1	0.1	0.19	0.18	0.21	0.08	0.08	0.04	0.04
C22 Levels of expertise	0.286	0.05	0.1	0.4	0.2	0.1	0.05	0.05	0.03	0.03
C23 Moral quality	0.571	0.05	0.05	0.1	0.2	0.3	0.1	0.1	0.05	0.05
C24 Psychological qualities	0.143	0.4	0.3	0.1	0.05	0.05	0.05	0.05	0	0
B10 Rent-seeking behavior	0.400	0.05	0.08	0.25	0.2	0.2	0.08	0.08	0.04	0.04
C25 Political interests	0.500	0.05	0.1	0.4	0.2	0.1	0.05	0.05	0.03	0.03
C26 Economic benefits	0.500	0.05	0.05	0.1	0.2	0.3	0.1	0.1	0.05	0.05
B11 Irrational decision-making behavior	0.200	0.09	0.13	0.23	0.24	0.14	0.13	0.04	0	0
C27 Extreme risk partiality of decision makers	0.143	0.4	0.3	0.2	0.1	0	0	0	0	0
C28 Information asymmetry	0.571	0	0.05	0.2	0.3	0.2	0.2	0.05	0	0
C29 Method defects or errors	0.286	0.1	0.2	0.3	0.2	0.1	0.05	0.05	0	0

Table 5 displays the results of the Chien et al. study (2014) who identified and assessed the critical risk factors that could occur in a BIM project.

Table 5: Critical Risk Factors of BIM Project (Chien et al., 2014)

Factor	Impact analysis	Probability	Risk Index	Risk Ranks
F1. Project experience inadequate	2	4	8	4
F2. Lack of software compatibility	2	5	10	2
F3. Model management difficulties	2	4	8	4
F4. Inefficient data Interoperability	2	5	10	2
F5. Management process change difficulties	1	5	5	10
F6. Inadequate top management commitment	1	2	2	13
F7. Workflow transition difficulties	2	3	6	7
F8. Lack of available skilled personnel	3	4	12	1
F9. Increase in short-term workload	1	4	4	12
F10. Rise in short-term costs	2	4	8	4
F11. Additional expenditure	2	3	6	7
F12. Lack of BIM Standards	1	5	5	10
F13. Unclear legal liability	2	3	6	7

In the European region, a considerable number of LSTIPs are run in the Northern and Western areas of Europe. The most important risks that could be confronted in Northern Europe are ordered as financial, construction, managerial, and natural and environmental risks (Xiang, 2010). Furthermore, the majority of the risks encountered in Western Europe are considered as financial, construction, natural and environmental, technical and economic risks (Husang and Baker, 2007). Both regions in Europe face common risks in the financial, construction, and natural and environmental categories. Interestingly, managerial risks reveal that Western European projects are administered better than North Europe and are also strictly coordinated within the projects. However, Western Europe has a predisposition to face technical and economic risks in comparison to Northern Europe.

The Persian Gulf and North Africa are the two main regions of the Middle East that are actively operating LSTIPs at the present time. In the Persian Gulf area, the most important risks confronted in LSTIPs are ordered as managerial, technical, natural and environmental, financial and political risks (Al-Sabah et al., 2014). Moreover, in the North Africa area, the most significant risks in LSTIPs are considered to be technical, managerial, financial, legal, economic, political, and natural and environmental risks (Al-Sabah, 2012). Two of the Middle Eastern zones could encounter risks either in the same or different categories. The common risks confronted in the Persian Gulf and North Africa indicate that there are poor relations among stakeholders in managerial terms, inadequate experience in technical terms, cost overrun or financial insufficiency in financial terms and the high risk of earthquakes and floods in natural and environmental terms. Alternatively, the economic and legal risks in North Africa differ because this region has a weaker economy and is governed with different regulations in comparison to the Persian Gulf area.

Although Europe and the Middle East are divided into various regions, this does not change the fact that the confronted risks could show both very common factors and significant differences. Therefore, it is more efficient to classify Europe and the Middle East under two main headings to provide a detailed analysis that everyone could benefit from.

In order to assess the risks of LSTIPs, a risk breakdown structure should be formed by initially identifying the risks and then distributing the identified risks into categories. In these types of large projects, risk assessment is complicated. Thus, by constituting an appropriate hierarchical risk breakdown structure in these projects, the process of the project could be oriented towards a positive direction and resolve indecisiveness of multi-risks.

2.3 Types of Risks in LSTIPs

Large-scale transport infrastructure projects (LSTIPs) are developed structures which emerged from the essential necessity of fast-paced and convenient transportation in gradually growing populations. Multiple risks such as technical, financial, economical, political, construction, management, natural & environmental and legal risks may be encountered in LSTIPs.

2.3.1 Construction Risk

During the construction phase of a project, operating and delivering the project successfully is a crucial process and any emergence of risks could lead to the postponement or even failure of the project. Construction risks relate to the complications that contractors, sub-contractors and clients could encounter in the implementation of the project (Lessard and Miller, 2001). These risks are mainly brought about in situations where the scope of the project encounters changes, planning is maintained at a poor level, construction techniques are not applied accurately, safety and level of expertise is not a prior consideration and poor communication occurs with risk management consultants.

2.3.2 Technical Risk

Even though projects are carefully planned and thoroughly managed, problems are likely to arise unexpectedly. One of the most common reasons for this is the unidentified technical risks that mainly interfere in the construction stage of the project (London Bridge Associates, 2014). Technical risks emerge as a result of technical causes that lead to the failure of a project. Technical causes occur in the development and running process of projects and consist of all the elements that could jeopardize the success of projects (malfunctioning of equipment and materials, design variations and delays in scheduling, inadequate training of employees, etc.) (Xenidis & Angelides, 2005). Construction information Services (2014) assert technical risks are brought about by unfulfilled designs, insufficient scrutiny of sites, ambiguity of specifications as well as accessible and suitable materials.

2.3.3 Financial Risk

Financial risks are concerned with money related issues involving project finance in the implementation, operating and funding process (Jayasudha and Vidivelli, 2016). These types of risks comprise the supplying of capital, interest rates, leasing as well as incomings and outgoings of cash. (Wang et. al, 2000) The process of venturing, especially internationally, is a crucial matter in order to assure that the financial conditions of the agreement is profitable and financial compensation is feasible. Moreover, if the financial factors are not managed appropriately, the outcome will be bankruptcy. The duration of a construction project may last up to a few years therefore it is important to protect the financial rights of foreign engineering and construction firms.

2.3.4 Economical Risk

Because exchange rates fluctuate constantly, economic risks require critical attention in the planning of major projects. Currently, foreign capital has gained ground throughout numerous countries in construction projects that are financed privately, increasing the risk of depreciating domestic currency. Therefore, foreigners who lend money opt for the return in foreign currency. With the rising interest towards private financing, project managers and eventually consumers struggle with the risk of the devaluation of currency (El-Sayegh, 2008; Nevitt and Fabozzi, 2000).

Another important economic risk for construction projects is related to the alterations in interest rates. Construction projects, either in the long or short run, could require loans with changeable interest rates. Based on presumptions, predictions on forthcoming interest rates are taken into account in the calculation of the project costs. Forecasts cannot be completely accurate, however it is recommended to adapt projects according to the changeable interest rates even if the economy status is vague. (Nevitt and Fabozzi, 2000).

2.3.5 Political Risk

When undertaking an enterprise in business terms, risks regarding politics and regulations are inevitable. These risks influence all facets of a project from construction to completion stages, including the choice of sites and marketing process. Foreign states may intervene in the flow of business, hindering the project due to events such as civil disobedience, war and industrial relations movements (Ashley and Bonner, 1987). Alterations in the law, the declaration of the state of emergency and expropriation of property are few of the major political risks. In this sense, the evaluation of these risks becomes complex. Assumptions on political risks are made by sponsors or in the worst case by lenders. (Youjie, 2003).

2.3.6 Managerial Risk

Managerial risks emerge when a project could not be fulfilled within a determined budget and specified time frame (Imbeah and Guikema, 2009). Controlling the cost of a project, assuring its quality, managing human resources and maintaining productivity are all concerned with managerial risks (Kangari, 1995). These risks comprise strategic planning and corporate governance risks that affect the achievement of the goals and the adherence to the current work plan in construction projects. The most major managerial risks are related to faults, safety, the quality of labour, efficiency and competency (El-awad, 2015). The identification, assessment and management of such risks are carried out by the senior management of the firm.

2.3.7 Natural and Environmental Risk

Natural risks are related to geological and meteorological systems which bring about hazards such as earthquakes, hurricanes, floods, tsunamis, landslides etc. Thus, these conditions could not be controlled in financial terms of the project. Similarly, environmental risks encompass the status of the weather and soil as well as environmental effects. One of the most common environmental risks that are neglected in the construction site is pollution. In situations that require the installments of roofing systems, maintenance of equipment, storage of construction materials etc., pollution is likely to occur. Even basic incidents such as accidental damage given to pipes and tanks could cause the leakage of chemicals (Patil and Vichare, 2017).

2.3.8 Legal Risk

Regulations, legislations and liabilities relating to construction projects bring along their legal risks. Of course, these differ from country to country as every government implements its legal system for construction industries (Levitt et al., 1980). Legal risks involve issues such as labour and safety laws, work permits, contracts, joint ventures, property rights etc. By paying critical attention to these matters in the planning stage, legal challenges could be prevented. This could be done by consulting legal services or adhering to the policies applied by the government (Sears et al., 2010).

2.4 Multi-Criteria Decision-Making

MCDM is a method that ensures the selection of the best alternative among numerous criteria that is applied at the same time. This method has shown rapid developments both theoretically and practically in the decision analysis field. With its powerful logic structure, it has been accepted successful in decision making and covers a broad application area. MCDM represents an approach as well as comprises of techniques and methods that are designed to assist people in making appropriate choices on their value judgments concerning multiple, contrasting criteria that have different values.

According to Keeney (1992), MCDM consists of three steps: firstly; the relevant criteria is identified, secondly; the numerical measurements of the effects of this criteria on alternatives as well as the eigen vectors of this criteria are identified and thirdly; a numerical assessment process is followed to determine the order of each alternative. The main aim of the MCDM in problems is to decide on the best alternative that satisfies to the highest extent in terms of all relevant criteria. (Chatterjee and Chakraborty, 2012; 385).

2.4.1 Analytical Network Process Method

In 1996, Thomas L. Saaty proposed the ANP method that offers effective and realistic solutions to complicated decision making problems. ANP is defined as a multiple attribute decision making method that covers qualitative values in addition to quantitative values, by modelling the problem in a hierarchical structure and by considering the relationships and interactions among criteria formed by the model. (Saaty,1999; Alptekin,2010). Analytical Hierarchical Process (AHP) provides a basis for ANP and focusing on unidirectional modelling in hierarchical form. Unlike AHP, ANP, instead of a unilateral relationship, deals with the decision making criteria in hierarchical structure, concerning interactions, inner-and-outer dependencies, mutual interactions and feedback without considering the level among sub-criteria and its alternatives. Numerous researchers have carried out studies in the area of the ANP method. Table 6 displays a list of these multiple studies and their researchers.

Table 6: Studies conducted with the application of the ANP method

Authors	**Application area**
Shahram, Masoumeh, Alieh, Abdolreza and jolanta (2017)	To evaluate the critical factors of the application of nanotechnology in the construction industry
Jeon, Kim, Park and Lee (2017)	To rank a set of potential Acquisition and Development candidates within a multivariate set of attributes systematically
Hashemi, Karimi and Tavana (2014)	To deal with the interdependencies among the criteria, and the traditional Grey relational analysis to better address the uncertainties inherent in supplier selection decisions.
Becker, Becker and Salabun (2017)	To support decisions of the experts
Çakmak and Çakmak (2014)	To analyze the main causes of disputes which occur in the construction industry
Bharti, Giri and Jayant (2015)	To proposes a structured model for evaluating and selecting a Green Supply Chain Strategy
Lin and Yang (2016)	To conduct weighted analysis of the candidate projects using the quantitative procedures of ANP
Ramani and Sruthi (2016)	To compute the project performance on the basis of the effects of Earned Value Management indices

Lu, Lin and Ko (2007)	To deal with the degree of risk for the main activities of an urban bridge project
Aydoğan and Köksal (2013)	To assess the priorities of the determined risk factors in partner selection for International Construction Joint Venture
Chen, Zhou and Zhang (2011)	To select optimal supplier in construction
Jia, Ni, Chen, Hong, Chen, Yang and Lin (2013)	To better understand the level of Risk Management practice by means of Risk Management maturity measurement.
Dikmen, Birgönül, Ozorhon and Sapcı (2010)	To identify the determinants of business failure in construction and to predict the failure likelihood of construction companies
Piantanakulchai (2005)	To prioritize a set of alternatives by using ANP model
Hussey and Malczewski (2016)	To housing quality evaluation
Chatterjee, Bandyopadhyay, Ghosh and Kar (2015)	To assess the relative importance of different factors responsible for preservation and restoration of ecological balance
Sujatha and Sridhar (2017)	To map the spatial propensity of debris flow
Datta, Saha, Ray and Das (2016)	To select an appropriate islanding-detection techniques for a particular renewable energy powered distributed generation application
Pandey and Agrawal (2014)	To solve the decision problem, where attributes of decision parameters form dependency networks.
Phong, Phuc, Quyen (2017)	To proposes a quantitative model for selecting a material supplier

To analyse this type of structure (to analyse large projects), MCDM methods are applied. MCDM methods were established to obtain transparency and shed light on the decision making process, and is mainly used to measure the levels of the risks. Among these methods, the AHP (Analytical Hierarchical Process) method is mostly preferred as it identifies solutions for problems encountered during risk assessment. Yet, since this method is a unilateral assessment method that is not equipped with interaction and feedback characteristics among risk factors, its application becomes inadequate during the risk assessment phase (Valipour, 2013). In this case, it is more appropriate and efficient to apply the AHP method to alternative selections. The ANP method, an expanded version of AHP, is composed of feedback and dependency (interactions) properties, therefore; is convenient for risk assessment in this research study. Furthermore, it was revealed in the same study that no single investigation exists in this focus area covering both Europe and the Middle East regions.

2.5 Knowledge-Based System

Knowledge-based systems are a main component of artificial intelligence. Chamiak and McDermott (1986) have described artificial intelligence as the exercise of the mental faculties by using the computational models.

A knowledge-based system (KBS) is a computer system which produces and utilizes understanding from various kinds of assets, statistics and data. Those systems help in fixing problems, especially complicated ones, through making use of artificial intelligence standards. These structures are generally deployed in problem-fixing processes and in guiding humans to gain knowledge, make decisions and take actions.

Moreover, experts working in the area of artificial intelligence strived to develop decision support programs in the 2000's that had an intelligence level and subtituted humans in solving problems (Akerkar and Sajja, 2010). Although these early programs paved the way for human intelligence, they became inefficient and unsuccessful when the program faced complex real life problems. This situation was not noticed until the 1970s. According to Feigenbaumin (1988), a knowledge capacity of the program was essential for the existing problem solving capability. With this modification made, rapid advancements were made in artificial intelligence which began to be known as knowledge-based systems.

Some research studies have been carried out on knowledge based systems such as Xianbo et al. (2016) who developed knowledge-based decision support system for risk management, Nilashi et al. (2015) who proposed a knowledge-based expert system for assessment of the performance level of a green building, Serpell et al. (2016) who introduced a knowledge-based system to solve the problems of risk management in construction projects, Motava and Almarshad (2013) who developed integrated knowledge-based system to obtain information and knowledge of building maintanence to help defensive maintanence decisions and Yildiz et al. (2014) recommended a knowledge-based risk mapping tool to assess the risk-related variables that can result in cost overrun in international markets.

With limits of recent computerized project-control systems, construction projects could be conducted and managed substantially with the implementation of various computer-based software that are known as knowledge-based systems. Knowledge-based softwares are widespread computer systems that are deployed to solve multiple complications.

2.5.1 Expert Systems

The past of expert systems associated with Information and Communication Technologies (ICT) does not date back so far. Expert systems or knowledge based systems began to be developed by those engaged in artificial intelligence since the 1950s. Expert systems can be defined as a computerized system used to find a solution to a problem in the relevant area (Hart, 1986).

In recent years, there has been gradual increase in knowledge-based risk management systems such as Tian et al. (2018) who proposed a novel method to set up a risk matrix for assessing protection risks in oil and fuel enterprise, Limao et al.

(2017) who developed a demster-shafer approach to construction safety risk perception, Xia and Chen (2011) who designed a decision making model in supply chain risk system, and Wauters and Vanhoucke (2016) who used artificial intelligents methods for the prediction of the final duration of a project.

Knowledge based systems or expert systems can be evaluated in two points of view (Becerra- Fernandez, 2000). The first is presented in Figure 7 and is formed of three main components from the perspective of the user. These components include user interface, smart program and problem database.

User: The person who generally knows that problem.

- User interface: can be thought as a user window in knowledge based systems. Users could solve the current problems by checking the system through this interface. The user interface can provide users with the necessary functions to exercise data, however does not allow users to access this data. Examples of the functions that users can perform are; providing clarification, questioning the smart program, showing results, providing graphical output, recording and printing results.
- Smart program: It is a black box that solves the problems of the user. By working on several rules the user is not familiar with, the user's desired results are produced.
- Problem database: It is a work area that reads input and writes ouput of the system. It composes all data on the current problem.

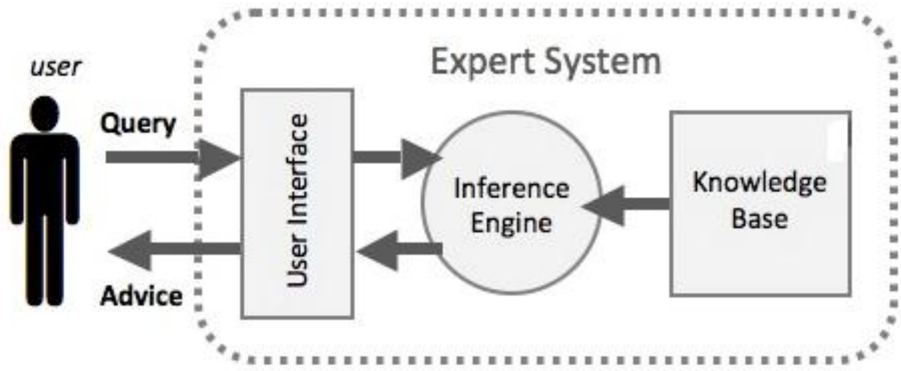

Figure 7: Common expert system structure from the user perspective (Triphati, 2011)

The second perspective, Figure 2 indicates how expert systems are viewed from the eye of the knowledge engineer. It possesses two main components; expert system shell and smart program.

2.5.1.1 Expert System Shell

The expert system shell (development shell) forms the development context. It is a set of tools that facilitates the forming of data within the smart program. The expert system shell includes functions such as the configuration of data collected from experts, the elimination of faults and the development of data. The computer engineer who defines this task is named the knowledge engineer. A development shell is made up of three subcomponents; acquisition tool, developer interface and test database (Sihwi et al., 2016).

Acquisition tool: It serves as a knowledge base editor and enables the knowledge engineer to regulate.

Developer interface: It composes extended features that facilitate the knowledge engineer in the development process. The knowledge engineer is able to make alterations and conduct tests on the knowledge base.

Test database: It consists of sample problems fulfilled successfully in advance on an expert system.

Besides the expert system shell, the second component that knowledge engineers interpret expert systems is smart program. This smart program has a crucial difference from smart programs known by users. The knowledge engineer, unlike the user, can see data in the black box.Smart program consists of two subcomponents; knowledge base and inference engine.

Knowledge base: is formed of all relevant, domain specific, problem-solving data collected from various resources by a knowledge engineer. Knowledge base consists of useful data for the solution of problems that are thought be solved in expert systems. Data in rule-based expert systems are expressed in rules.

Inference engine: by translating the data recorded in the knowledge base, the inference engine draws results from it. This mechanism enables the expert system to make decisions by using a knowledge base in the expert system to receive solutions. Two methods have been developed to make inferences with the use of data in the knowledge base. The first method is the forward chaining method that commences from the beginning of the problem (IF) and reaches the result section (THEN). This method aims to draw conclusions by considering whether or not the conditions could be provided in all rules with inductive logic. The second method is the backward chaining method that commences from the target situation and proceeds backwards towards the initial conditions. When solving the problem, it is begun with the end of the rule being the result (THEN) sentence and implemented on conditional (IF) sentences to draw a conclusion. This chaining is based on the deductive principle.

From a general point of view apart from the user and knowledge engineer, the summary of expert system's working principles is presented in Figure 8.

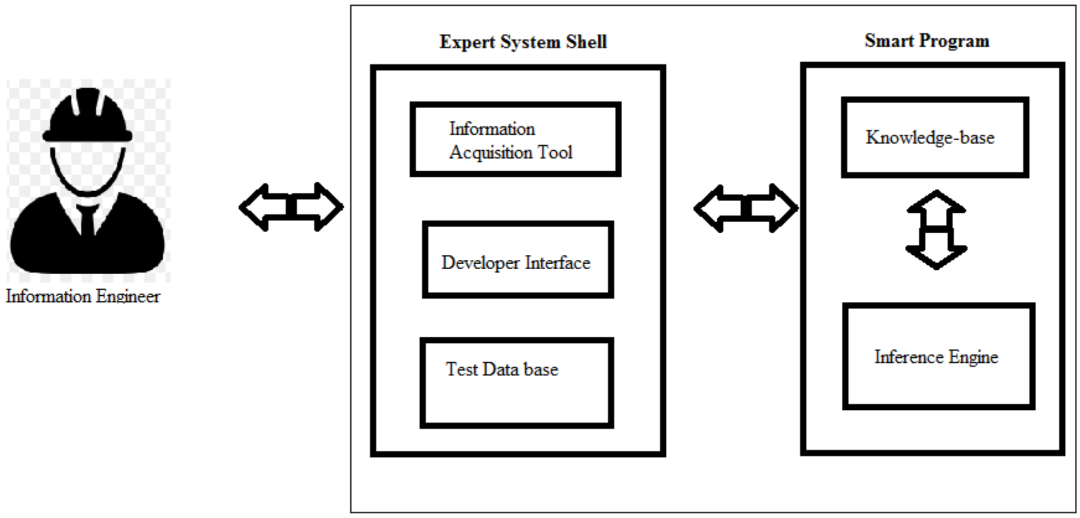

Figure 8: Common expert sytem structure from the Information Engineer Perspective (Akarker, 2010)

2.6 Decision Support System

Firms collect data increasingly day after day. As a result, finding specific data from the accumulation of data becomes a very complicated task. Several computer based systems have been developed to simplify this process. In order words, these systems are an aid in decision making. They contribute to the resolution of complex problems by providing efficient use of data and models (Xianbo et al., 2016).

The functions of the Decision Support System include (Hadiguna et al., 2014):

- Structuring decision making
- Organizational planning
- Organizational control
- Automating decisions
- Providing background data

- Providing information to executives and managers

The advantages of the Decision Support System are (Pick, 2008):

- Increase in the number of tested alternatives
- Rapid responses in unexpected situations
- Instant analysis quality
- Advanced communication
- Further control
- Decrease of cost
- Save time
- Use data resources more efficiently

Decision support systems are divided into five within themselves as follows (Demirkıran and Delen, 2013);

2.6.1 Data Base Decision Support System

This system is divided into two within itself.

2.6.1.1 On-Line Analytic Processing

Online analytical processing (OLAP) is a structure used for the repetition of data, for reporting and analysis, which forms the data in this way and provides fast access to the data. It is used for business intelligence solutions. The OLAP backplane is a convenient method for long-term analysis and it operates with flat file net. The OLAP structure analyzes the data with higher performance and provides reporting (Sharma et al., 2011).

2.6.1.2 On-Line Transaction Processing

On-Line Transaction Processing (OLTP) is a software program that can support applications with a focus on processing over the Internet (Marwah et al., 2013). Typically OLTP performs data entry, uploading, updating, deleting and short operations. Because these processes are carried out, the system runs fast. However, when complications occur, a few problems could be encountered and in this manner, the system begins to slow down.

2.6.2 Document-Based Decision Support System

Document-based Decision support system manages the data components where information is stored and provides access to that data. Data can be divided into three different categories; written, visual and audible. Document-based Decision support system is used in areas that (Ru et al., 2013):

• Provide tools for accessing server networks, mass memory, and information.

• Use artificial intelligence as an aid in classifying information for clarity.

2.6.3 Web-based Decision Support System

Web-based Decision Support System was developed for instant support. The Web-based DSS command investigates how different alternative solutions can be found using the web interface to determine the problems of various sources. Web-based DSS could be perceived as a DSS (knowledge-based, document-based, communication-based and model-based mixture) system (Banias et al., 2011).

2.6.4 Communication Decision Support System

Communication Decision Support System provides information sharing, cooperation and coordination among human groups. The user interface consists of shared information, support, user, a system combined with intra-group communication (Gorsevski et al., 2013).

2.6.5 Knowledge-Based Decision Support System

For numerous unstructured and semi-problems, solutions could be too complex and may require an intelligent system (Zavadskas et al., 2012). Advanced DSS come into play as sub-components of the knowledge base. Knowledge base components compose of many components such as artificial neural networks, intelligent spies, faulty logic and computer based. The tools used for information based DSS are called smart DSS.

2.7 The Importance of Decision Making

The environment in today's business world has become quite complex. This complexity requires decisions to be taken in a new form and often in group settings. Teamwork and group decision making have become the most important criteria among all decision making processes (Cui et al., 2014). With this, decision support systems, in other words, expert systems, have improved. Therefore, this study focuses on the development of a knowledge-based decision support system tool to enable a faster and more efficient decision support for LSTIPs in Europe and the Middle East.

Chapter 3

METHODOLOGY

3.1 Introduction

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 (Enright, 2012) and the Bridge project in the Middle East (Yusufoğlu, 2017) 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.

The identification of relative importance is significant in terms of revealing which characteristics of the quality of information are kept in the foreground by stakeholders. This way, when the quality of information is required for evaluation or development, the necessity of which characteristics are considered mainly and primarily will be presented.

In the process of decision making, the use of MCDM methods assists managers in assessing alternatives and provides more efficient use of business resources. MCDM is an analytical method that provides a simultaneous assessment of numerous strategic and operational factors that are measurable and immeasurable. At the same time, it involves many people in the decision making process.

The MCDM method is used in solving problems consisting of multiple criteria. In recent years, one of the decision supporting methods that has gained importance and become widespread is the Analytic Network Process (ANP). The ANP takes account of feedbacks among outer-and-interdependencies, enabling more efficient and practical solutions of problems in decision making (Becker et al., 2017). In normal circumstances, tasks are carried out by human experts, however; through an expert system, this expert knowledge is transferred to a computer software program (Ooshaksaraie et al., 2012). According to Irani and Kamel (2014), expert systems should be regarded as computer programs that display an experts' knowledge and inference process to unravel complicated problems, presenting the possible solutions and recommendations in identifying risks and making decisions.

More importantly, this chapter explains implementation procedure of the RII. Beside this, it describes the development and implementation of ANP model for LSTIPs. Furthermore, case studies testing process is clearly stated. In addition to this, development of LSTIPs Risk identification and Decision supporting tool steps are defined.

3.2 Significances of the Risk in LSTIPs

In the light of the literature, various methods and techniques regarding risk assessment have been applied to these kinds of projects including Diab et al. (2012) who used risk assessment techniques to improve highway construction project performance, Abdollahzadeh and Rastgoo (2015) who used fault tree and event tree analysis methods based on fuzzy logic to assess risks in a bridge project and the Vishwakarma et al. (2016) study which imposed the relative importance index (RII) method on a highway project. Encountering risks 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. Due to complexities and lengthy time durations of LSTIPS, numerious risks could emerge which may affect the project fate. Table 7 shows the the risk categories, ranging from construction risks, financial risks, technical risks, managerial risks to economical and political risks. For the assessment of the risks, the risk factors (under the categories) arising in LSTIPs were obtained from a comprehensive literature analysis as displayed in Table 7.

.

Table 7: 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
√		√					√	Suh (2000)
√			√		√	√		Ellis et al. (2003)
	√		√		√	√		Youjie (2003)
		√	√	√	√	√		Ghosh et al. (2004)
			√		√	√	√	Pathan et al. (2013)
√		√	√	√		√	√	El-sayegh (2008)
√	√		√		√	√		Caltrans (2007)
	√	√		√	√	√	√	Wang et al. (2015)
	√		√	√			√	Ebrahimnejad et al. (2010)
√	√	√	√			√		Abdollahzadeh (2015)
√	√	√	√		√	√	√	Choudhry (2014)
√			√	√		√	√	Li et al. (2012)
		√						Thomas et al. (2005)
√				√				Vishambar et al. (2016)
√	√							Diab et al. (2012)
		√	√			√	√	Zayed (2008)
√	√		√	√		√		Molenaar (2005)
				√				Kumar (2017)
√			√			√	√	Vishwakarma et al. (2016)
√		√			√		√	Iut (2012)
√		√	√	√	√			Zou et al. (2010)
√	√	√			√	√		NTP (2005)
√			√	√		√	√	El-Sayegh and Mansour (2015)
	√	√	√		√	√	√	Chien et al. (2014)
√	√	√	√	√	√	√	√	Khodeir et al. (2014)
√			√	√		√	√	El-Sayegh and Mansour (2015)
	√	√	√			√	√	Hwang et al. (2017)

3.2.1 Research Method

A questionnaire survey was adapted and developed from the El-Sayegh study (2015) in order to collect demographic information of respondents and to sort risk factors under categories related with LSTIPs. Figure 9 illustrates the process which was followed to identify and assess the risks of LSTIPs in this study. Figure 9 shows an extensive literature review, eight risk categories for risk identification and categorization, and obtained fifty risk factors. According to the results of the questionnaire administered afterwards, one hundred and eighty-seven contacts are established. On the other hand, the output section of Figure 9 highlights that the results of the questionnaire are subject to risk assessment and ranking. As a result, fifty relative importance index and significance levels of risks were determined by the path presented in Figure 9.

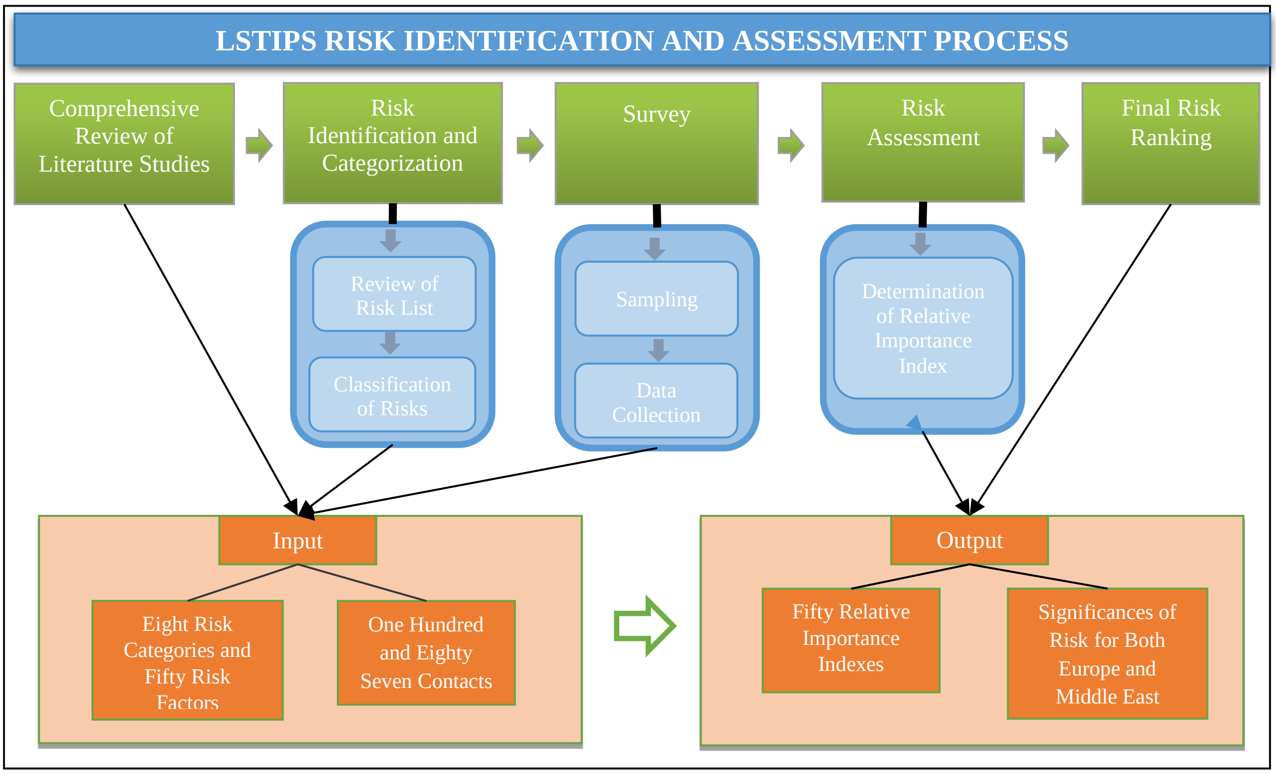

Figure 9: Risk Identification and Assessment Process for LSTIPs in Europe and Middle East by RII

3.2.2 Sampling

This study focuses on contractor and engineering consulting firms specialized in LSTIPs and located in both Europe and the Middle East. Large-scale firms build mega projects at an average annual cost ranging from one hundred million to twenty billion dollars (Flyvbjerg et al., 2013). The list consists of 250 international contractor and engineering consulting firms. The sample is exclusive for large-scale firms.

3.2.3 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 fifty 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.

3.2.4 Implementation of RII

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. RII is computed as (El-sayegh, 2015):

$$\boldsymbol{RII} = \frac{\sum \boldsymbol{W}}{\boldsymbol{A} \times \boldsymbol{N}}$$

W is the weight given to each factor by the respondents and ranges from 1 to 5.

A = the highest weight = 5

N = the total number of respondents

3.3 Analytic Network Process

ANP is the expanded version of Analytic Hierarchical Process (AHP) developed by Saaty (2005) for the decision making of complex problems. ANP is generated from control hierarchies, clusters, nodes, the interrelationship among nodes and the interrelationship among clusters (Piantanakulchai, 2005). The most salient feature that distinguishes ANP from AHP in the decision making phase is the bilateral structure that is interactive within one another in lieu of a top-down unilateral structure.

The implementation of ANP commences with the establishment of the model and the formulation of the problem, followed by pair-wise comparisons among nodes and clusters which are essential for the optimization of the problem. This can clearly be seen in Table 8, adapted from the scale developed by Saaty (Husang, 2007) where eigen vectors are identified and unweighted super matrix is formed subsequently with the use of the weights in pair-wise comparisons. After this, unweighted matrix normalizes all columns by converting them into stochastic matrix (the sum of columns equaling one) to determine the weighted supermatrix. Finally, by taking the power until the values of weighted supermatrix converge, the limit supermatrix is obtained.

Table 8: Saaty's (2005) ranking scale

Intensity of importance	Definition
9	Extremely important
7	Very strongly important
5	Strongly important
3	Moderately important
1	Equally important
1/3	Moderately not important
1/5	Not important
1/7	Less important
1/9	Minimally important
2,4,6,8 and 1/2,1/4,1/6,1/8	Intermediate values

Briefly, the ANP method consists of four main stages (Dagdeviren et al., 2005);

- Identifying the aim and developing the model*:* At this stage, the criteria and factors are specified. Interrelated criteria are formed in the same cluster, and then the same process is applied to the factors. Following this approach, the interaction and dependency among clusters are determined, and the network structure is created. The formation of ANP is illustrated in Figure 10.

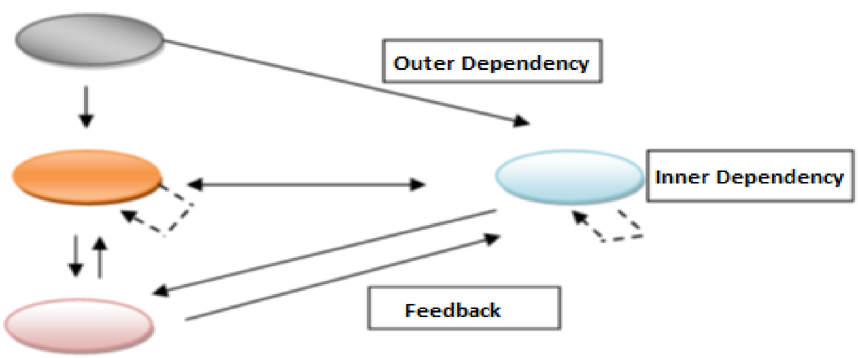

Figure 10: Structure of ANP method (Karsak et al., 2002)

- Calculation of eigen vectors after obtaining the pairwise comparison matrix: With interactive criteria and factors, pairwise comparisons are made. In the ANP method, pairwise comparisons are completed with the application of the 1-9 Saaty Scale, which is also used in the AHP method. In addition, each obtained pairwise comparison matrix's consistency ratio is calculated to ensure that the value is below 0.1.

- The formation of the limit super matrix: The obtained eigen vectors are entered into the unweighted super matrix columns. Subsequently, the sum of each column is normalized to form the weighted super matrix. Finally, to equalize the priority weights, the power of the weighted super matrix is raised until it converges, and the obtained new matrix is named as the limit super matrix.

- Selecting the priority factors: The obtained limit super matrix displays the priority weights of the factors and/or compared criteria. The factor and the criterion with the largest value indicate the highest priority in terms of the effect on the decision-making process.

3.3.1 Development and Implementation of ANP Model for Large-scale Transport Infrastructure Projects

Because of the increasing population and the advancements made in technology in today's world, the necessity of LSTIPs has escalated proportionally. However, the augmentation of such projects also leads to increased risks, which has a negative influence on the construction process as well as the objectives of the project. Hence, the main purpose of applying the ANP model in this study is to prioritize the risks in recent European and Middle Eastern LSTIPs and to facilitate efficient and rapid decision making for the planning stage of the project. ANP has been utilized in several research studies covering highway corridor planning (Piantanakulchai, 2005), sustainable mobility (Bottero and Lami, 2010), environmental impact assessment (Chen et al., 2011), risk assessment of gas refinery engineering procurement and construction (EPC) projects (Valipour et al., 2013), and best value contractor selection (Hasnain et al, 2017).

The procedure undertaken in this research study to form and implement an ANP model is as follows:

- The identification and categorization of risks: a systematic literature review and the formation of a "risk breakdown structure" by classifying and determining risk factors based on expert views;
- The formation of a limit super matrix by:
  - Developing an ANP model: creating interactions among clusters and nodes, inner and outer dependency and feedback in the Super Decisions software;
  - Making pair-wise comparisons of the risk factors and risk categories, followed by the estimation of eigen vectors and the consistency ratio to form the matrix to enable expert decision makers to make pair-wise comparisons using Saaty's scale. Identifying eigen vectors from the comparisons as well as determining and checking the consistency ratio of comparisons; and

- Prioritizing risk factors and their categories: specifying the degree of importance of the compared risk factors and categories from the obtained limit super matrix.

3.4 Testing the Results of Proposed ANP Model

3.4.1 Case Studies

This section presents two LSTIPs constructed in Europe and the Middle East. This section of the study was aimed to test the consistency of the risk factors' priority orders identified in Europe and the Middle East.

Information related to these companies and projects was collected via interviews. Interviews that lasted from thirty minutes to an hour were arranged with project managers. General information regarding the company and projects was obtained, and the risks and factors confronted in projects were discussed. Note that the priority order for the encountered risks was required.

3.5 Knowledge-Based Risk Identification and Decision Supporting Tool with Exsys Corvid

Expert system tools incorporate the basic components of expert system in the representation of a software development setting. Exsys Inc. launched the Exsys Corvid® in 2001 placing emphasis on advancing knowledge automation systems that enable the stages of the process and the logic rules applied in decision making to be converted into a depiction of rules.

By means of Exsys Corvid®, non-programmers are guided towards creating interactive web applications that apprehend the logic and procedures applied in solving problems in web-based environments. With Exsys Corvid®, four primary alternatives in system delivery are possible: Java Servlet through HTML or through Adobe Flash, off-line as Java executable and Java Applet in a web page.

For the organization and structuring of rules, Corvid applies Action Blocks and Logic. Formed of tree diagrams, Logic block enables the arrangement of sets of relevant rules in order to simplify them in building and sustaining, as well as to indicate discrepancies in the logic. A variety of paths are available for building the logic as they are free-form to a high degree. With this, it becomes possible to organize the rules according to how the thoughts of the domain experts are based on the problem. The focus of Action Blocks is on smart questionnaires and offers an alternative path to build rules formed of more processes. Moreover, Command Blocks, similar to a script, exist in Corvid that explain the continuous process of system execution. They enable ‘if’, ‘while’ and ‘for’ loops.

3.5.1 Development of LSTIPs Risk Identification and Decision Supporting Tool

Expert systems are a widely used logic method in the field of high technology. In a variety of industries, computer programs are used that always perform the necessary functions of a qualified expert, help industries easily with a program that can be easily consulted, and decide on the conditions appropriate to their situations and to the solutions of these situations. Expert system package programs, which are used efficiently in many areas, increase productivity and minimize the amount of time loss.

The procedure undertaken in this research study to develop and implement the risk identification and decision supporting tool is as follows:

- Information was gathered by means of questionnaire from the firms and priority values were obtained from the ANP model in this study;
- The variables were loaded on the expert system shell and were defined primarily by selecting the add data in the Prompt section;
- The data was defined in tables and priority orders were transformed to a series of logical IF-THEN rule clusters for Europe and the Middle East;
- The proposed LSTIPs risk identification and decision supporting tool were tested to display the outcomes.

3.5.1.1 The Information Gathering

LSTIPs' risk identification and decision supporting tool (LSTIPs RiDECS), that could be deployed as a decision support system in the planning phase, was developed with the use of information gathered from the firms as well as the priority values obtained from the ANP model that is presented in Table 6-12.

A questionnaire was conducted to project managers and construction managers working in contracting firms, as well as civil engineers working in engineering consulting firms in both regions. Table 9 shows the roles of employees working in the two types of firms in Europe and the Middle East in numbers. It is clearly seen that majority of the respondents who took part in the questionnaire are project managers in both Europe and the Middle East.

Table 9: Number of the Roles of Respondents according to Regions

	Contracting Firm (n)	Engineering Consulting Firm (n)
Europe	Project Manager = 42 Construction Manager = 21	Civil Engineer = 35
Middle East	Project Manager = 34 Construction Manager = 29	Civil Engineer = 26

Project managers, Construction managers and civil engineers were required to rank the risk categories importance level. Table 10 and Table 11 represent the importance level of risk categories in percentage form for each project role of respondents as well as the average importance level of the total respondents for Europe and the Middle East. According to the results based on Europe in table 10, project managers view financial risk as the highest importance level in risk categories and the lowest importance level is selected as legal risk by construction managers.

Table 10: The Importance Level of Risk Categories according to Respondents and Firms in Europe

	Construction risk	**Managerial risk**	**Financial risk**	**Technical risk**	**Economic risk**	**Legal risk**	**Natural and Environmental risk**	**Political risk**
Project manager	87,14	78,57	94,76	64,29	84,76	60,48	81,90	65,24
Construction manager	87,62	65,71	85,71	68,57	60,00	43,81	80,00	56,19
Civil engineer	85,14	66,86	85,71	66,86	60,00	49,71	76,00	57,71
Firms Average	86,63	70,38	88,73	66,57	68,25	51,33	79,30	59,71

On the other hand, the results for the Middle East in Table 11 state that the highest importance level in risk categories is natural and environmental risk for civil engineers and legal risk holds the least importance level among risk categories according to civil engineers.

Table 11: The Importance Level of Risk Categories according to Respondents and Firms in the Middle East

	Construction risk	**Managerial risk**	**Financial risk**	**Technical risk**	**Economic risk**	**Legal risk**	**Natural and Environmental risk**	**Political risk**
Project manager	79,41	91,76	91,76	65,29	60,00	67,06	79,41	80,59
Construction manager	84,83	69,66	88,28	77,24	75,17	71,72	75,17	48,97
Civil engineer	86,15	80,00	93,85	66,15	87,69	33,85	98,46	73,85
Firms Average	83,46	80,47	91,30	69,56	74,29	57,54	84,35	67,80

Participants were asked to indicate the type of LSTIP they last worked in as well as state the risks involved in that particular project. The responses were organized into risk factors and project types categories that are presented in Table 12 for Europe and in Table 13 for the Middle East. These tables display a variety of risk factors that could be confronted in specific projects.

Table 12: Risk Factors according to Project Types in Europe

Category	Tunnel	Bridge	Highway	Railway	Subway
Construction	• Change in scope of work • Cost escalation • Inadequate construction planning	• Change in scope of work • Poor coordination among the consultants • Cost escalation • Inadequate construction planning	• Change in scope of work • Cost escalation • Inadequate construction planning	• Change in scope of work • Poor coordination among the consultants • Cost escalation	• Change in scope of work • Poor coordination among the consultants • Cost escalation
Management	• Loss of control • Poor communications among stakeholders • Unrealistic scheduling	• Unrealistic scheduling • Poor communications among stakeholders • Loss of control	• Loss of control • Unrealistic scheduling • Contractors' poor management ability	• Improper project feasibility and planning • Unrealistic scheduling	• Contractors' poor management ability • Improper project feasibility and planning • Loss of control
Financial	• Design variations • Financial failure of contractor • Inadequate site information	• Financial strength of client • Financial failure of contractor • Design variations • Inadequate site information	• Financial strength of client • Financial failure of contractor • Inadequate site information	• Financial failure of contractor • Design variations	• Financial failure of contractor • Incomplete or inaccurate cost estimate • Financial strength of client
Technical	• Poor definition of scope • Inadequate time allocation • Insufficient or incorrect design information	• Poor definition of scope • Material suitability and accesability and shortage • Inadequate time allocation	• Employment of inexperienced designers • Insufficient or incorrect design information • Changes to the technology used • Inadequate time allocation	• Employment of inexperienced designers • Poor definition of scope • Material suitability and accesability and shortage	• Insufficient or incorrect design information • Poor definition of scope • Employment of inexperienced designers
Economic	• Exchange rates fluctuation • Resources availability • Economic crisis	• Economic crisis • Resources availability • Increased materials cost • Exchange rates fluctuation	• Increased materials cost • Exchange rates fluctuation • Economic crisis	• Economic crisis • Resources availability	• Increased materials cost • Exchange rates fluctuation
Legal	• Inappropriate contracting • Conflict in laws • Breach of agreements	• Breach of agreements • Conflict in laws • Inappropriate contracting • Misinterpretation • Nationalism and local protectionism	• Breach of agreements • Inappropriate contracting • Misinterpretation • Nationalism and local protectionism	• Breach of agreements • Conflict in laws • Inappropriate contracting	• Inappropriate contracting • Breach of agreements
Natural & Environmental	• Flood • Unforeseen adverse site conditions • Water pollution	• Earthquake • Flood • Unforeseen adverse site conditions	• Flood • Unforeseen adverse site condition • Water pollution tions	• Unforeseen adverse site condition • Flood	• Water pollution • Flood
Political	• Changes of planning • Rigid bureaucracy	• Bribery • Changes of planning • Unsupportive government policies	• War and civil disorder • Rigid bureaucracy • Changes of planning	• Changes of planning • War and civil disorder	• Rigid bureaucracy • War and civil disorder

Table 13: Risk Factors according to Project Type in the Middle East

Category	Tunnel	Bridge	Highway	Railway	Subway
Construction	• Change in scope of work • Cost escalation • Faulty construction techniques • Inadequate construction planning	• Change in scope of work • Cost escalation • Inadequate construction planning	• Change in scope of work • Cost escalation • Inadequate construction planning • Poor coordination among the consultants • Faulty construction techniques	• Change in scope of work • Faulty construction techniques	• Inadequate construction planning • Cost escalation
Management	• Loss of control • Contractors' poor management ability	• Poor communications among stakeholders • Loss of control	• Loss of control • Poor communications among stakeholders • Contractors' poor management ability	• Loss of control Unrealistic scheduling • Contractors' poor management ability	• Loss of control
Financial	• Financial strength of client • Inadequate site information	• Financial strength of client • Financial failure of contractor • Design variations • Inadequate site information	• Financial strength of client • Financial failure of contractor • Inadequate site information	• Financial strength of client • Inadequate site information	• Inadequate site information • Financial strength of client
Technical	• Poor definition of scope • Employment of inexperienced designers • Material suitability and accessibility and shortage	• Poor definition of scope	• Employment of inexperienced designers • Poor definition of scope • Insufficient or incorrect design information • Inadequate time allocation	• Employment of inexperienced designers • Poor definition of scope	• Poor definition of scope • Employment of inexperienced designers
Economic	• Increased materials cost • Resources availability • Economic crisis	• Resources availability • Increased materials cost • Exchange rates fluctuation	• Increased materials cost • Exchange rates fluctuation • Economic crisis • Resources availability	• Economic crisis • Resources availability	• Increased materials cost • Exchange rates fluctuation • Resources availability
Legal	• Inappropriate contracting • Breach of agreements • Nationalism and local protectionism	• Breach of agreements • Conflict in laws • Inappropriate contracting	• Breach of agreements • Inappropriate contracting • Conflict in laws • Nationalism and local protectionism	• Nationalism and local protectionism • Inappropriate contracting	• Conflict in laws • Breach of agreements • Nationalism and local protectionism
Natural & Environmental	• Flood • Unforeseen adverse site conditions • Earthquake	• Earthquake • Flood • Water pollution • Wind	• Flood • Unforeseen adverse site condition • Water pollution tions • Wind	• Unforeseen adverse site condition • Flood • Wind	• Water pollution • Flood
Political	• Unsupportive government policies • Rigid bureaucracy	• Rigid bureaucracy • Changes of planning	• War and civil disorder • Rigid bureaucracy • Changes of planning • Unsupportive government policies	• Changes of planning • Rigid bureaucracy • Unsupportive government policies	• Rigid bureaucracy • Unsupportive government policies • Changes of planning

Furthermore, respondents were asked to indicate the duration of the LSTIP they were last involved in, and, in response to this, state the economic conditions that may change in the course of time. Table 14 reflects the economic conditions that may vary according to the duration of the LSTIPs.

Table 14: Points considered according to the Duration of LSTIPs in Europe and the Middle East

Project Duration	Definition
2 < years	Consider Exchange rates, taxes and Inflation
2 > years	Consider Exchange rates and Taxes

Table 15 shows the intervals of priority orders importance level for both Europe and the Middle East. By attaining the midpoint of the priority values obtained from the ANP model, the levels of risks that could arise are detected. Therefore, the decisions to be taken against significance levels are determined.

Table 15: Decisions taken according to the Priority Order Levels of Risk Factors

Level	Europe risk factor Priorities Interval (out of 1)	Middle East risk factor Priorities Interval (out of 1)	Decision for the Risk Factors
High	0.0793 – 0.1336	0.0869 – 0.1154	Accept
Medium	0.0141 – 0.0792	0.0301 – 0.0868	Mitigate or Transfer
Low	0.0032 – 0.0140	0.0016 – 0.0300	Eliminate or Neglect

Because the types of LSTIPs, the roles in the project, the duration of the project and the risk factors that could arise are large in number, it is not possible to place all rules under one structure tree. Therefore, a tree structure is formed directed towards the rules that could be carried out by the designed tool. Figure 11 shows a structure tree displaying the the risk factors that could be confronted at a moderate degree, the decisions that could be taken against risks and the regional significance values. The structure tree is based on the construction category of a tunnel project by a contracting firm in European LSTIPs in which a project manager worked for over two years. Similarly, Figure 12 presents the risk factors that could be confronted at a high degree, the decisions that could be taken against risks and the regional significance values. The structure tree is based on the financial category of a bridge project by a contracting firm in Middle Eastern LSTIPs in which a construction manager worked for over two years.

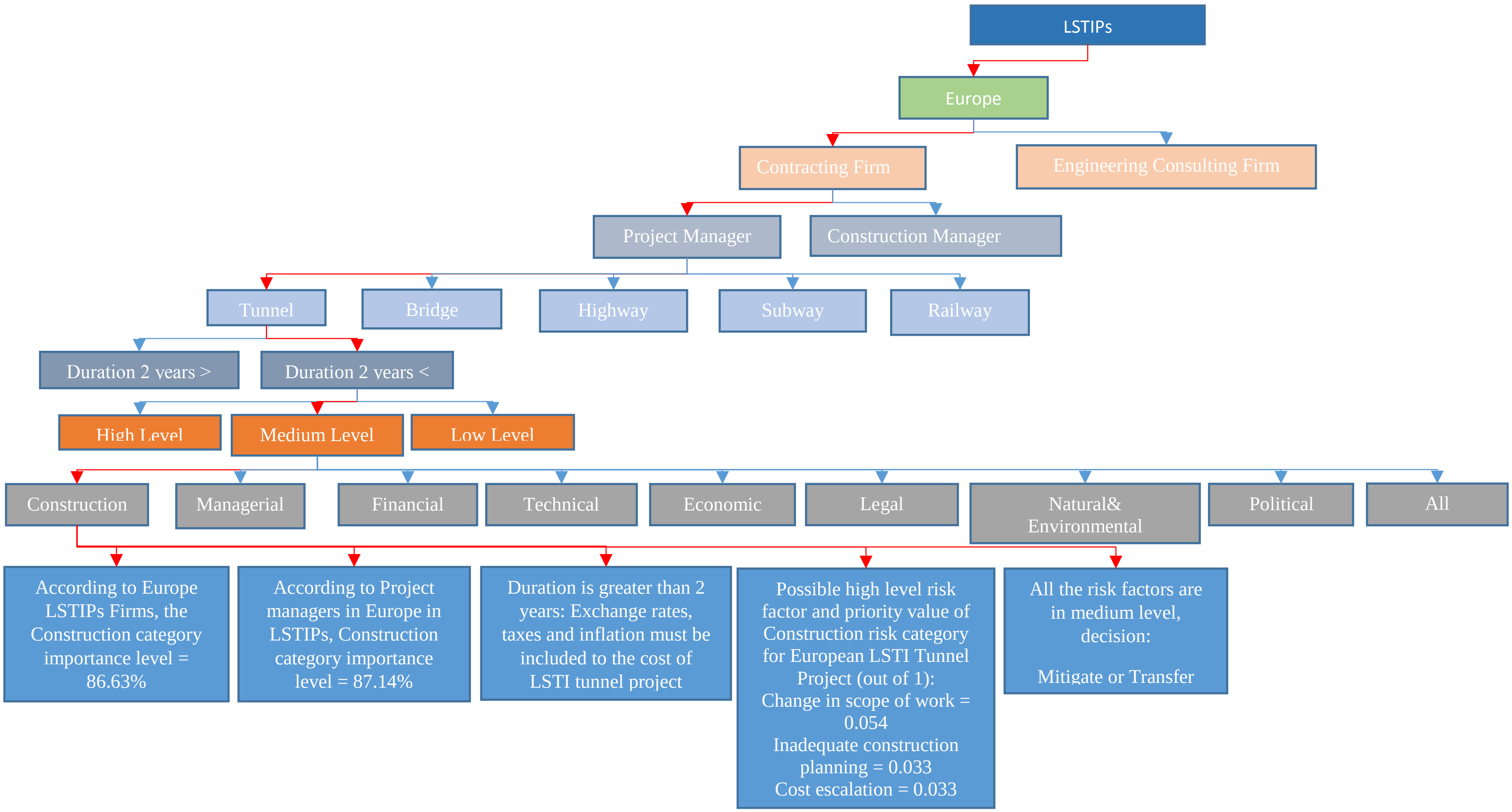

Figure 11: Europe Structure Tree

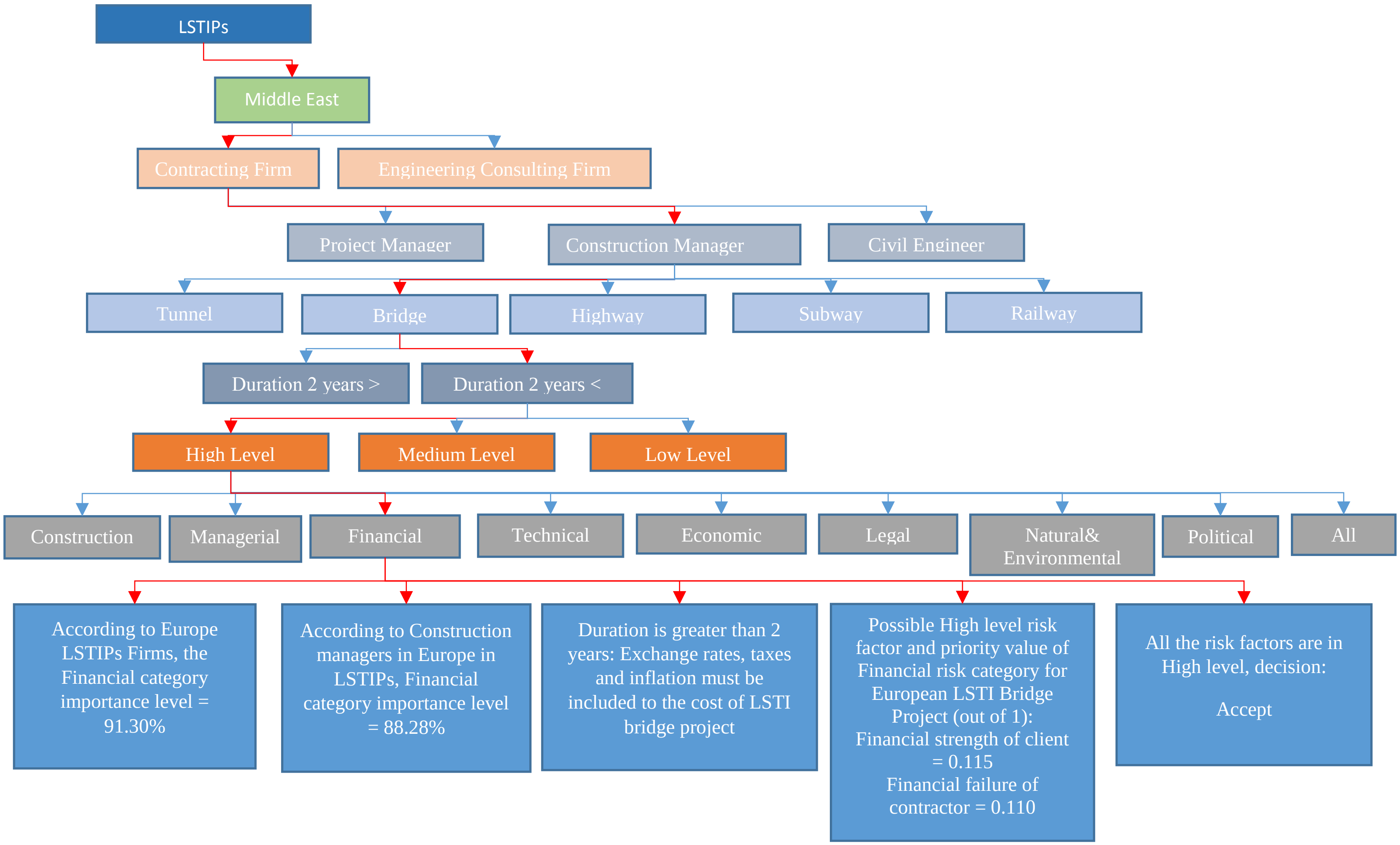

Figure 12: The Middle East Structure Tree

A LSTIPs’ risk identification and decision support tool is developed by defining the data in the aforementioned tables and figures as well as the priority orders obtained for Europe and the Middle East in a series of logical IF-THEN rule clusters, as seen in Figure 13, and converting them to an expert system shell called Exsys Corvid®.

IF:
Where will the Large-scale Transport Infrastructure Project be implemented? Europe Region
AND: What type of LSTIP firm are you working for? Contracting Firm
AND: What is your role in the current LSTIP? Project manager
AND: What is the type of the current LSTIP? Tunnel
AND: [Duration] >2
AND: Which level of risk factors are you seeking for in the current LSTIP? Medium level
AND: Which risk category are you seeking for in the current LSTIP? Construction

THEN:
Answer: According to Europe LSTIPs Firms, the construction risk category importance level = 86.63%
Answer: According to Project Managers in Europe in LSTIPs, the construction risk importance level =87.14%
Answer: Duration is greater than 2 years: Exchange rates, taxes and inflation must be included to the cost of LSTI Tunnel Project
Answer: Possible medium level risk factors and priority values of Construction risk category for European LSTI Tunnel Project (out of 1): Change in scope of work = 0.054, Inadequate construction planning = 0.033, Cost escalation = 0.033
Answer: All the risk factors are in medium level, decision: Mitigate or Transfer

Figure 13: A Sample for Logical IF-THEN Rules

Chapter 4

ANALYSIS AND RESULTS

4.1 Introduction

In the past ten years, Large-scale transport infrastructure projects (LSTIPs) have become a major area of interest and have gained prior importance for 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 (Locatelli et al., 2017). 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 (Salling and Banister, 2010), reflection of issue of risk in transport infrastructure projects (Miller and Szimba, 2013*)* and cost overruns in LSTIPs (Cantarelli et al., 2013). 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 part is to identify the risks that could occur in European and Middle Eastern LSTIPs and to determine significances of the risks in these projects. Based on the identified risks and their significances, this part also aims to create a guideline for effectively managing risks in further research studies conducted in the two regions and in the planning phases of similar projects.

This part has been structured as follows; firstly, the risks that occur in European and Middle Eastern LSTIPs have been identified via literature review and expert group meeting. Secondly, the significances have been analysed with the use of RII method and then discussed. Thirdly, an ANP model has been developed using the defined risk factors. Fourthly, the risks have been sorted by means of Super Decisions software. Fifthly, the risk priorities have been compared and the deficiencies of risk types in Europe and the Middle East have been detected. Sixthly, other priority orders of risks from two different case studies have been examined. Finally, with the orders of risk categories and factors, a reference tool has been proposed for future projects in Europe and the Middle East.

4.2 Analysis of RII

Experience is known as being well prepared and dominant when involved in or exposed to a circumstance or subject. On the other hand, a project is a "temporary" effort, meaning a beginning and ending date exists. Works that last eternally or have an indefinite start date are not entitled as projects. In completion of the project, a unique product is attained. For instance, the construction of a building is a "one-of-a-kind" work for the constructor because even if he has completed many similar buildings in the past, many features like the location, the architecture, the area, the used material and the arising problems will surely differ in previous constructions. Likewise, the conditions of the construction area could vary in projects. Therefore, the roles of stakeholders in the project and the experiences they have gained as well as the different characteristics of the project are highly important.

In table 13, a total of 98 participants from Europe and 89 participants in the Middle East took part in the study. In terms of their experience, 37 of the respondents from Europe and 32 of the respondents from the Middle East have an experience of 20 years or more. This shows that a large number of qualified individuals in knowledge and practice are involved in LSTIPs in both regions. Table 16 presents the respondents' background in terms of role and years of experience in LSTIPs. Data was collected from respondents who work for two different types of firms; 67.36% of respondents work for contracting firms and 32.62% of respondents work for engineering consulting firms. In addition, the roles of the contacts in the firms compose of 40.64% project managers, 26.73% construction managers and 32.62% civil engineers respectively. The table 16 clearly illustrates that out of all the respondents from Europe, most of the project managers (9.62%) have experience over twenty years, most of the construction managers (4.27%) have an experience of 11 to 20 years and most of the civil engineers (6.94%) have experience over twenty years.

Table 16: Respondents' Role and Years of Experience in LSTIPs according to Regions

		Respondent's Background			
		Contracting Firm		Engineering Consulting Firm	
		Project Manager (40.64%)	Construction Manager (26.73%)	Civil Engineer (32.62%)	Total
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 16 also highlights that out of all the respondents from the Middle East, majority of the project managers (7.48%) have more than 20 years experience, most of the construction managers (6.41%) have more than 20 years experience and majority of the civil engineers (4.27%) have an experience of five to ten years.

Risks factors and categories were obtained by reviewing the literature. By means of a questionnaire, each of these factors was rated on a scale of 1 to 5 according to their degrees of importance. Following, the relative important index method was used to evaluate these results. Based on the RII results, the risk factors were ranked. Table 14 displays the RII results of risks factors that could arise in European and Middle Eastern LSTIPs. The highest RII values for each risk category in Europe are ordered respectively as; change in scope of work in construction category, contractors' poor management ability in management category, financial strength of client in financial category, poor definition of scope in technical category, resource availability in economic category, inappropriate contracting in legal category, flood natural and environmental category and rigid bureaucracy in political category.

Furthermore, in table 17 the highest RII values for each risk category in the Middle East rank respectively as; change in scope of work in construction category, loss of control in management category, financial strength of client in financial category, poor definition of scope in technical category, increased material cost in economic category, inappropriate contracting in legal category, water pollution in natural and environmental category, and unsupportive government policies in political category.

Table 17: Results of RII for LSTIPs implemented in Europe and the Middle East

Category	**LSTIPs Risk Priority**						
		Europe			**Middle East**		
	Risk factors	**RII**	**Cronbach α**	**Rank**	**RII**	**Cronbach α**	**Rank**
Construction	Change in scope of work	0.83	0.82	1	0.81	0.78	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	0.80	7	0.74	0.79	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
Financial	Rentals	0.73	0.83	7	0.72	0.81	7
	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
Technical	Employment of inexperienced designers	0.80	0.78	3	0.80	0.75	2
	Changes to the technology used	0.74		6	0.79		4
	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

Table 17: Continuation of Results of RII for LSTIPs implemented in Europe and the Middle East

	Inadequate time allocation	0.73		7	0.76		5
Economic	Inflation	0.73	0.79	7	0.74	0.76	6
	Exchange rates fluctuation	0.79		4	0.76		5
	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
Legal	Permits and licenses	0.74	0.76	6	0.72	0.74	7
	Conflict in laws	0.76		5	0.76		5
	Breach of agreements	0.82		2	0.80		2
	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	0.81	5	0.76	0.80	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
Political	Changes of planning	0.76	0.77	5	0.79	0.77	4
	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

RII analysis was used to determine risk factors' significance levels in the categories of construction, management, financial, technical, economic, legal, natural environmental and political. The risk factors of the categories were empirically tested and validated by principal component analysis. A summary of the results is shown in Table 17. Overall and individual measures of sampling adequacy were computed to assess the appropriateness of the data for RII analysis. Values greater than 0.5 are considered acceptable. The reliability for each of the extracted factors is established by checking these factors for internal consistency using Cronbach's alphas. Cronbach's alpha (α) is based on the average correlation between variables within each factor, where a value of 0.7 is the minimum acceptable value. Examination of the Cronbach's alpha values revealed that all the reliability coefficients α for the risk factors listed in Table 17 have acceptable levels of reliability. Some risk category were more reliable than others. For the European results, the risk factors "financial", "construction", and "natural&environmental", have the highest reliability coefficients α with values of 0.83, 0.82, and 0.81 respectively. For the Middle Eastern results, the risk factors "financial", "natural&environmental", and "management", have the highest reliability coefficients α with values of 0.81, 0.80, and 0.79 respectively.

4.2.1 Discussion of RII Results

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 (Mirza, 2013). 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 (Amoatey et al., 2014). It is a commonly held view that one of the primary causes of project failure is the poor definition of scope (Kerzner, 2017). 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 (Eduardo et al., 2010). 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 (Wang et al., 2016).

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 (Memon, 2011). Due to the lack of flood risk assessment methods, huge economic costs arise and people may be exposed to dangerous circumstances (Morss, 2005). Thus, flood risk assessment has become an indispensable component in projects. With the incompletion 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 (Taylan et al., 2014).

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 (Rozenfeld, 2010). 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 (Le-Hoai, 2008). 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 (Zou et al., 2007). Unsupportive polices, 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 (Karim et al., 2014).

4.3 Analysis of ANP Model

4.3.1 The Identification and Categorization of Risks

Risks confronted during the planning, construction and completion phase of a project are one of the reasons that could lead to the failure of LSTIPs. Generally, risks are described as ambiguous conditions or events that have a negative effect on the duration, cost and quality of a project. In addition, as the size and the complicacy of LSTIPs enlarge, the number of risks also increases. Therefore, the identification of risks in LSTIPs plays an important role in the fate of the project.

Risks are identified according to a standard list of risks based on relevant literature studies, documents and records as well as interviews and focus groups in which all possible risks are discussed. In this study, the risk factors confronted in LSTIPs were obtained from an extensive literature analysis, as presented in aforementioned Table 4. Subsequently, a questionnaire adapted from the El-Sayegh study (2015) was distributed to 250 contracting and engineering consulting firms operating in European and Middle Eastern LSTIPs. Out of these firms, 187 responded to the questionnaire. The questionnaire aims to evaluate the orders of importance of the factors and categories of risks that could occur in LSTIPs. The respondents are comprised of project managers, construction managers and civil engineers working for the firms.

Additionally, each category and each factor are scored on a scale ranging from "1 unimportant" to "5 extremely important". Correspondingly, the importance orders of 60 risk factors presented under 8 categories were evaluated.

Table 18 displays the respondents' area of experience in tunnels, bridges, railways, highways and subways. It is clearly seen that a large number of the respondents in Europe and the Middle East have been involved in highway projects. As seen in Table 18, the respondents' experience in different types of LSTIPs ranking from highest to lowest in percentage is; 16.04% in highways, 11.76% in tunnels, 10.16%

in subways, 8.02% in bridges and 6.42% in railways for Europe. In the Middle East, the order of experience for respondents is 20.32% in highways, 10.16% in tunnels, 9.09% in bridges, 4.81% in railways and 3.21% in subways.

Table 18: Respondents' Area of Experience in LSTIPs according to Regions

Regions	**Respondent's Area of Experience in LSTIPs**				
	Tunnel (21.93%)	Bridge (17.11%)	Highway (36.36%)	Railway (11.23%)	Subway (13.37%)
	Number	Number	Number	Number	Number
Europe	22 (11.76%)	15 (8.02%)	30 (16.04%)	12 (6.42%)	19 (10.16%)
Middle East	19 (10.16%)	17 (9.09%)	38 (20.32%)	9 (4.81%)	6 (3.21%)

Table 19 displays the degree of importance and the cost of LSTIPs for two of the regions. Furthermore, the table indicates the past experiences of respondents in LSTIPs and the large risks undertaken by firms. Table 19 also states the respondents' average project cost (approximate cost of the fulfilled projects the respondent has taken part in).

The results clearly show that majority of the respondents in Europe (34.69%) and similarly, majority of the respondents in the Middle East (34.83%) have taken part in projects that cost between 1 and 5 billion dollars. On the other hand, the least number of respondents in Europe (13.26%) and the Middle East (12.35%) were involved in projects worth over 10 billion dollars.

Table 19: 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%)
6-10 billion	29 (29.59%)	19 (21.34%)
1-5 billion	34 (34.69%)	31 (34.83%)
<1 billion	22 (22.44%)	28 (31.46%)

The project managers, construction managers and civil engineers involved in Middle Eastern and European LSTIPs assigned values of importance according to the risk categories. Figure 17 and Figure 18 present graphs that illustrate the average of these importance levels. The data in the graphs clearly specify the degree of similar and contrasting responses among the three groups of respondents.

In Figure 14, the responses given by the three groups of respondents in European LSTIPs show a high degree of similarity in the construction, technical, and natural and environmental risk categories. Although construction managers and civil engineers give similar responses in managerial, financial, economic and political risk categories, differences are clearly observed in the project managers' responses.

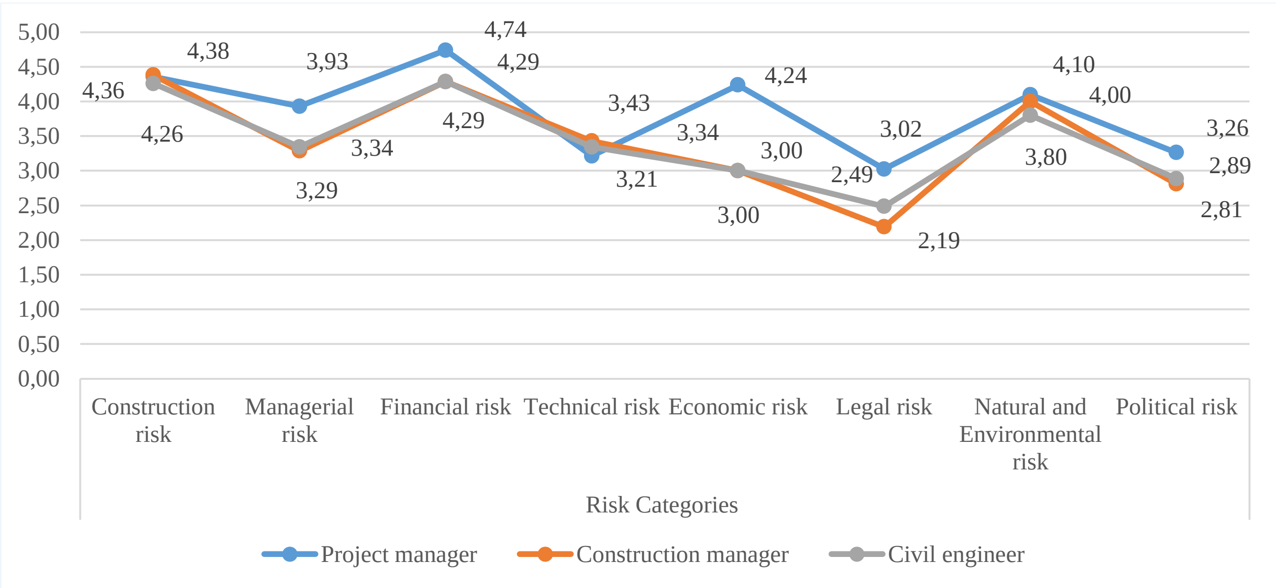

Figure 14: Comparison of Europe Respondents' Risk Categories in Importance Level

As seen in Figure 14, the most similar ratings among all risk categories in importance level were identified in the construction risk category with project managers (4.38), construction managers (4.36) and civil engineers (4.26). Likewise, Figure 14 also reflects similarities in ratings for project managers (4.74), construction managers

(4.29) and civil engineers (4.29) in the financial risk category. On the other hand, the least similar ratings are respectively; project managers (3.02), construction managers (2.19) and civil engineers (2.49) in the legal category.

In Figure 15, the responses given by three groups of respondents involved in Middle Eastern LSTIPs display notable differences in the managerial, economic, legal, natural and environmental, and political risk categories. However, similar responses are evident in the construction, financial and technical risk categories.

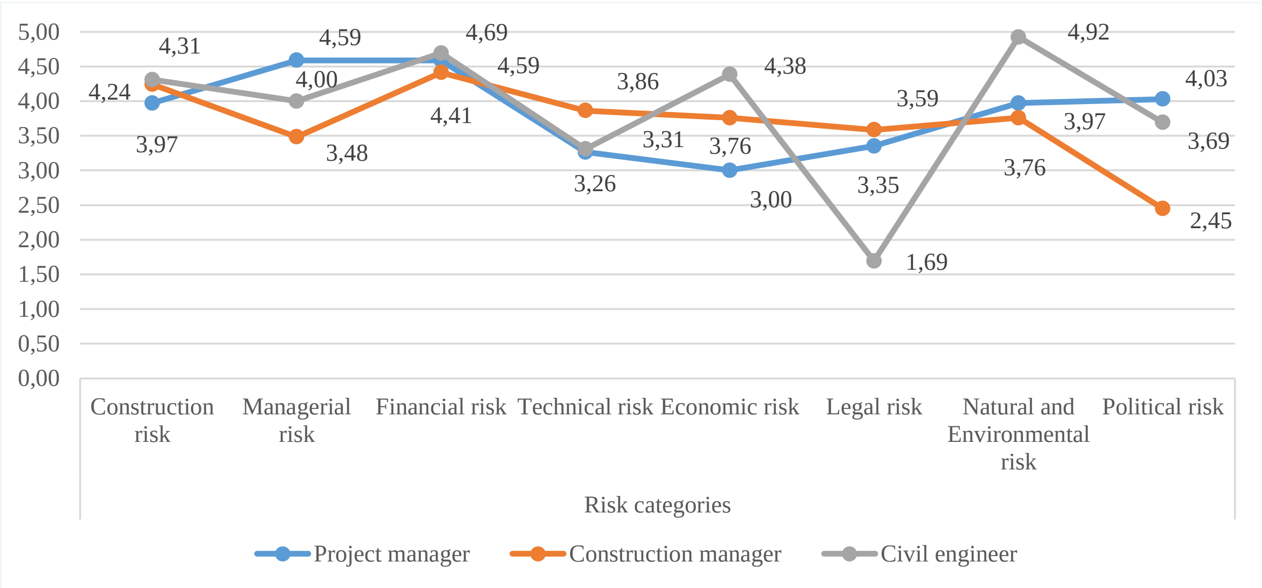

Figure 15: Comparison of the Middle East Respondents' Risk Categories in Importance Level

The most similar ratings among all risk categories in importance level were found in the financial risk category with project managers (4.59), construction managers (3.48), and civil engineers (4.00). Likewise, similarities in ratings are also displayed in the natural and environmental risk category for project managers (3.97), construction managers (3.76) and civil engineers (4.92). However, discrepancies in ratings are seen in the political category with project managers (4.03), construction managers (2.45) and civil engineers (3.69) in the legal category.

The nominal group technique (NGT) is used to sort a wide range of generated ideas in a priority order with the full contribution of group participants. This method enables all members to reach a consensus (Gallagher, 1993) and is applied to resolve conflicts and/or to make rapid decisions. Similarly, the collective notebook method (CNM) is a creative technique used individually to produce and record ideas in a notebook regarding a specified problem. After a certain period of time, a group meeting is conducted to gather, sort and develop the ideas of all participants (Martin et al., 2010). Both techniques are employed in large-scale projects to facilitate fast and joint decision making in the group. According to the priority orders, the factors were synthesized by applying the NGT and CNM with five experienced participants. Thus, forty risk factors were identified, with the five most important risk factors listed under each category. Table 20 presents the profile of the experienced participants group comprised of project managers, construction managers and civil engineers. The region they have worked in and their lengths of experience are also stated numerically in the Table 20.

Table 20: Experienced Participants' Group Profile

Regions		**Project Manager (40%)**	**Construction Manager (40%)**	**Civil Engineer (20%)**	**Total**
	Europe	1 (20%)	1 (20%)	-	2
	Middle East	1 (20%)	1 (20%)	1 (20%)	3
Years of experience for Europe	>20 years	1 (20%)			1
	11-20 years		1 (20%)		1
	5-10 years				-
	<5 years				-
Years of experience for Middle East	>20 years		1 (20%)		1
	11-20 years	1 (20%)			1
	5-10 years			1 (20%)	1
	<5 years				-

In table 20, a project manager with over 20 years of experience and a construction manager with 11-20 years of experience were contacted in Europe. Moreover, contact was made with a project manager with experience between 11 and 20 years, a construction manager with more than 20 years of experience and a civil engineer with 5 to 10 years of experience.

If not conducted properly, the process of identifying risks may finalize with misleading information. Therefore, it is essential to detect the relations among risks when obtaining risk factors and to categorize them into a clear-cut structure. Thus, after the relative importance indexes of the risk factors were obtained from the literature, the experienced individuals in the area of LSTIPs in both regions were contacted, and risk categories and factors were determined using NGT and CNM which are highlighted in Figure 16. Consequently, as shown in Figure 16, a risk breakdown structure (RBS) was formed by dividing the risks related to LSTIPs into eight main categories and then placing five risk factors under each of these main categories.

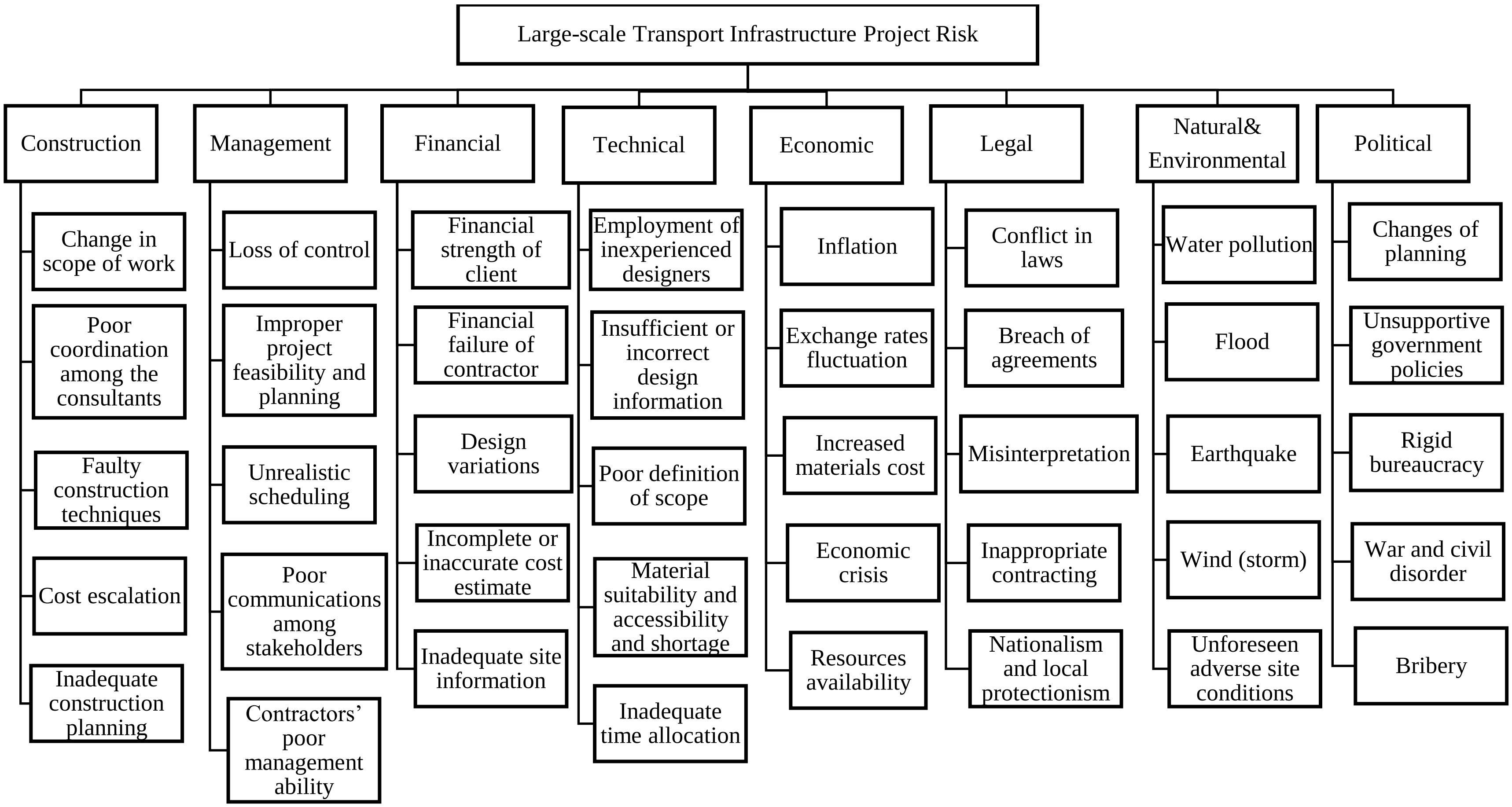

Figure 16: The Risk Breakdown Structure Created for LSTIPs

4.3.2 The Process of Obtaining Limit Super Matrix

Feedback and interdependency characteristics exist in the ANP method. Therefore, the criteria are dependent within themselves, as is possible with criteria dependent on other criteria. In terms of the literature based on ANP, the criteria regarding the dependency among clusters are defined as the outer dependency and the criteria relating to the dependency within the cluster itself are described as the inner dependency. Furthermore, because the ANP approach incorporates reciprocal interactions among the inner dependencies and the criteria, it ensures more effective and realistic solutions in the decision-making phase (Görener, 2009). According to the obtained hierarchical risk breakdown structure, by using Super Decisions software, an ANP model, as shown in Figure 17 and Figure 18, was constructed from the interactions between categories and factors and from the consideration of inner and outer dependencies.

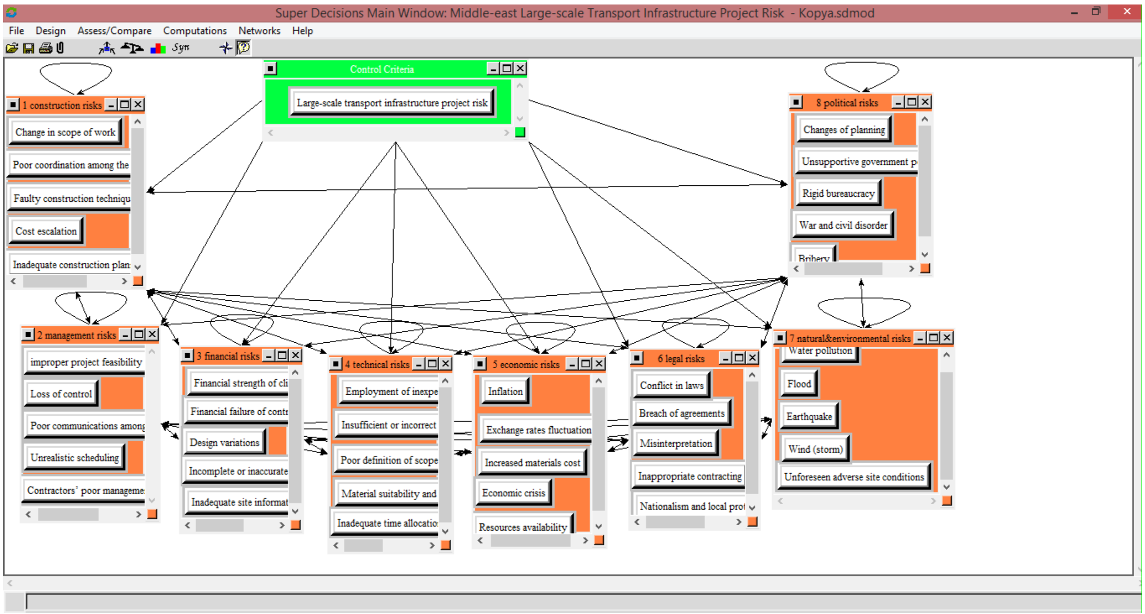

Figure 17: An ANP Model Developed for LSTIPs in Europe

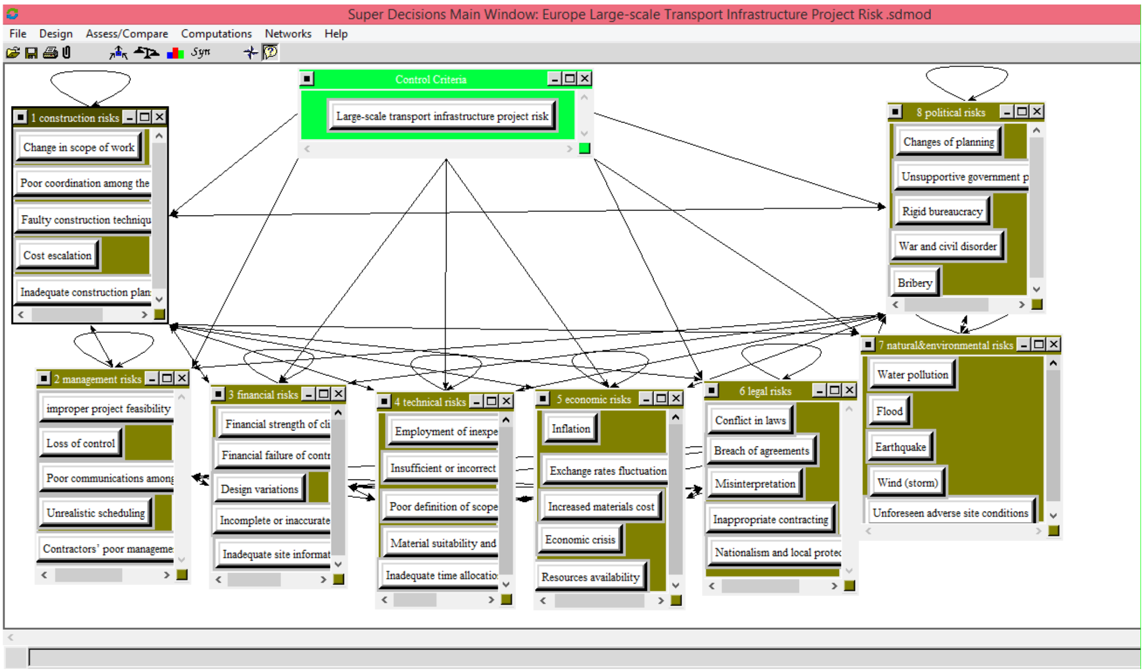

Figure 18: An ANP Model Developed for LSTIPs in Middle East

By using Superdecision software, the dependencies are assigned one by one to the risk category clusters as dependent on LSTIPs for Europe and the Middle East (eight risk categories); risk factors, also known as nodes are assigned under each cluster (five risk factors per cluster); and inner and outer dependencies are assigned within each category to form an ANP model, as seen in Figure 17 and Figure 18.

Afterwards, by forming the comparison matrices, the Saaty scale was distributed to twenty expert decision makers to use for completion. Table 18 shows the profile of the respondents who made pairwise comparisons. As illustrated, the respondents consist of project managers, construction managers and civil engineers. Information regarding which region they have worked in and their approximate years of experience in the field is clearly noted in Table 21. In the European region, contact was made with three project managers who range from 5 years of experience to over

20 years of experience in LSTIP, four construction managers who have experience from 5 years to 20 years and one civil engineer who has an experience of 11 to 20 years. In the Middle East, communication was established with four project managers having an experience ranging from 5 to 20 years, two construction managers (one with 5 – 10 and the other with more than 20 years of experience) and five civil engineers ranging from less than five years experience to 20 years.

Table 21: Pairwise Comparison of Respondents' Profile

		Project Manager (35%)	**Construction Manager (30%)**	**Civil Engineer (35%)**	**Total**
Regions	Europe	3 (15%)	4 (20%)	1 (5%)	8
	Middle East	4 (20%)	2 (10%)	6 (30%)	12
Years of experience for Europe	>20 years	1 (5%)			1
	11-20 years	1 (5%)	3 (15%)	1 (5%)	5
	5-10 years	1 (5%)	1 (5%)		2
	<5 years				
Years of experience for Middle East	>20 years		1 (5%)		1
	11-20 years	2 (20%)		1 (5%)	3
	5-10 years	2 (20%)	1 (5%)	4 (20%)	7
	<5 years			1 (5%)	1

Table 22 shows a blank sample of the comparison matrix that was to be completed by experts under the category of construction. The experts were required to fill in the highlighted spaces by using the values from the Saaty's ranking scale.

Table 22: A Sample of Comparison Matrix Presented to Experts

	Change in scope of work	Cost escalation	Faulty construction techniques	Inadequate construction planning	Poor coordination among the consultants
Change in scope of work	1				
Cost escalation		1			
Faulty construction techniques			1		
Inadequate construction planning				1	
Poor coordination among the consultants					1

For example, considering the construction cluster presented in Table 23, when the factor of faulty construction techniques is compared to the factor of inadequate construction planning, the value is 3, indicating that the factor of faulty construction techniques is moderately more important than the factor of the inadequacy of construction planning.

By making self-comparisons of the risk factors and the categories and by using the Super Decisions software simultaneously, the eigen vectors (order of priority) and the consistency ratios were obtained from the comparisons. Next, the values of consistency ratios were checked to ensure they were below 0.1. Among all pairwise comparisons that were made, a few examples both Europe and Middle East are displayed in Tables 23- 40.

In table 23, under the construction cluster of Europe, the eigen vector value with the highest risk factors (0.259) are; change in scope, cost escalation and faulty construction techniques. However, inadequate construction planning is the lowest in eigen vector value (0.082).

Table 23: Pairwise Comparison Regarding Construction Cluster for Europe

	Change in scope of work	Cost escalation	Faulty construction techniques	Inadequate construction planning	Poor coordination among the consultants	Eigen - vector
Change in scope of work	1	1	1	3	2	0.259
Cost escalation	1	1	1	3	2	0.259
Faulty construction techniques	1	1	1	3	2	0.259
Inadequate construction planning	1/3	1/3	1/3	1	½	0.082
Poor coordination among the consultants	1/2	½	1/2	2	1	0.138
Consistency Ratio (C.R) = 0.00222						

According to Table 24, the highest risk factor in eigen vector value (0.344) in the Middle East is the change in scope of work in the construction cluster. On the other hand, the lowest risk factor in eigen vector value (0.096) is faulty construction techniques.

Table 24: Pairwise Comparison Regarding Construction Cluster for Middle East

	Change in scope of work	Cost escalation	Faulty construction techniques	Inadequate construction planning	Poor coordination among the consultants	Eigen - vector
Change in scope of work	1	2	3	2	2	0.344
Cost escalation	1/2	1	2	1	2	0.209
Faulty construction techniques	1/3	½	1	½	1/2	0.096
Inadequate construction planning	1/2	1	2	1	2	0.209
Poor coordination among the consultants	1/2	½	2	½	1	0.140
Consistency Ratio (C.R) = 0.01954						

In table 25, the pairwise comparison matrix for Europe points out that loss of control in the managerial cluster has the highest eigen vector value of 0.384. However, poor coordination among stakeholders is lowest in importance with an eigen value of 0.068.

Table 25: Pairwise Comparison Regarding Management Cluster for Europe

	Contractors' poor management ability	Improper project feasibility and planning	Loss of control	Poor communications among stakeholders	Unrealistic scheduling	Eigen - vector
Contractors' poor management ability	1	5	1	5	4	0.368
improper project feasibility and planning	1/5	1	1/5	1	2	0.093
Loss of control	1	5	1	5	5	0.384
Poor communications among stakeholders	1/5	1	1/5	1	1/2	0.068
Unrealistic scheduling	1/4	½	1/5	2.0	1	0.084
Consistency Ratio (C.R) = 0.03701						

In the managerial cluster noted in table 26 for the Middle East, the contractor's poor management ability has the highest eigen vector value of 0.364 and the lowest eigen vector value of 0.107 in improper feasibility and planning.

Table 26: Pairwise Comparison Regarding Management Cluster for Middle East

	Contractors' poor management ability	Improper project feasibility and planning	Loss of control	Poor communication among stakeholders	Unrealistic scheduling	Eigen - vector
Contractors' poor management ability	1	3	2	3	2	0.364
Improper project feasibility and planning	1/3	1	1/2	1	1/2	0.107
Loss of control	1/2	2	1	2	2	0.239
Poor communications among stakeholders	1/3	1	1/2	1	1/2	0.107
Unrealistic scheduling	1/2	2	1/2	2	1	0.180
Consistency Ratio (C.R) = 0.01605						

In table 27, the financial cluster for Europe highlights that the highest eigen vector value is 0.310 as incomplete and inaccurate cost estimate and the lowest eigen vector value is 0.063 as design variations.

Table 27: Pairwise Comparison Regarding Financial Cluster for Europe

	Design variations	Financial failure of contractor	Financial strength of client	Inadequate site information	Incomplete or inaccurate cost estimate	Eigen-Vector
Design variations	1	0,2	0,25	0,5	0,33	0.063
Financial failure of contractor	2	0,33	0,5	1	0,5	0.116
Financial strength of client	3	0,5	1	2	1	0.211
Inadequate site information	5	1	0,5	3	2	0.298
Incomplete or inaccurate cost estimate	4	2	1	2	1	0.310
Consistency Ratio (C.R) = 0.03987						

According to table 28 indicating the financial cluster for the Middle East, the highest eigen vector value of 0.358 is inadequate site information and the lowest eigen vector value of 0.089 is designs variations.

Table 28: Pairwise Comparison Regarding Financial Cluster for Middle East

	Design variations	Financial failure of contractor	Financial strength of client	Inadequate site information	Incomplete or inaccurate cost estimate	Eigen-Vector
Design variations	1	0,33	0,33	1	0,33	0.089
Financial failure of contractor	3	1	0,5	3	1	0.231
Financial strength of client	1	0,33	0,33	1	0,33	0.089
Inadequate site information	3	2	1	3	2	0.358
Incomplete or inaccurate cost estimate	3	1	0,5	3	1	0.231
Consistency Ratio (C.R) = 0.01732						

In Table 29 considering the technical cluster for Europe, the lowest eigen vector value is 0.409 as inadequate time allocation and the lowest eigen vector value is 0.074 as insufficient or incorrect design information.

Table 29: Pairwise Comparison Regarding Technical Cluster for Europe

	Employment of inexperienced designers	Inadequate time allocation	Insufficient or incorrect design information	Material suitability and accessibility and shortage	Poor definition of scope	Eigen-Vector
Employment of inexperienced designers	1	4	4	1	0,33	0.220
Inadequate time allocation	3	3	3	3	1	0.409
Insufficient or incorrect design information	0,25	1	1	0,25	0,33	0.074
Material suitability and accessibility and shortage	1	4	4	1	0,33	0.220
Poor definition of scope	0,25	1	1	0,25	0,33	0.074
Consistency Ratio (C.R) = 0.03987						

In the technical cluster for the Middle East, illustrated in Table 30, the highest eigen vector value is 0.384 as material suitability and accessibility and shortage and the lowest eigen vector value is 0.108 as poor definition of scope, inadequate time allocation and employment of inexperienced designers.

Table 30: Pairwise Comparison Regarding Technical Cluster for Middle East

	Employment of inexperienced designers	Inadequate time allocation	Insufficient or incorrect design information	Material suitability and accessibility and shortage	Poor definition of scope	Eigen-Vector
Employment of inexperienced designers	0,33	1	1	1	0,33	0.108
Inadequate time allocation	0,33	1	1	1	0,33	0.108
Insufficient or incorrect design information	1	3	3	3	0,5	0.288
Material suitability and accessibility and shortage	2	3	3	3	1	0.384
Poor definition of scope	0,33	1	1	1	0,33	0.108
Consistency Ratio (C.R) = 0.01308						

Table 31 displaying the economic cluster for Europe highlights exchange rates fluctuations as the highest eigen vector value of 0.348 and inflation as the lowest eigen vector value of 0.058.

Table 31: Pairwise Comparison Regarding Economic Cluster for Europe

	Economic crisis	Exchange rates fluctuation	Increased materials cost	Inflation	Resources availability	Eigen-Vector
Economic crisis	0,5	1	0,5	2	0,25	0.103
Exchange rates fluctuation	3	2	1	3	2	0.348
Increased materials cost	1	2	0,33	4	0,33	0.153
Inflation	0,25	0,5	0,33	1	0,14	0.058
Resources availability	3	4	0,5	7	1	0.335
Consistency Ratio (C.R) = 0.07852						

In table 32, the economic cluster for the Middle East indicates that inflation and economic crisis has the highest eigen vector value of 0.330 and exchange rates fluctuation has the lowest eigen vector value of 0.085.

Table 32: Pairwise Comparison Regarding Economic Cluster for Middle East

	Economic crisis	Exchange rates fluctuation	Increased materials cost	Inflation	Resources availability	Eigen- Vector
Economic crisis	3	3	1	3	1	0.330
Exchange rates fluctuation	0,5	0,5	0,33	1	0,33	0.085
Increased materials cost	1	1	0,33	2	0,33	0.126
Inflation	3	3	1	3	1	0.330
Resources availability	1	1	0,33	2	0,33	0.126
Consistency Ratio (C.R) = 0.01732						

According to table 33, the legal cluster for Europe shows that the highest eigen vector value of 0.603 is breach of agreements and the lowest eigen vector value of 0.055 is nationalism and local protectionism and conflict in laws.

Table 33: Pairwise Comparison Regarding Legal Cluster for Europe

	Breach of agreements	Conflict in laws	Inappropriate contracting	Misinterpretation	Nationalism and local protectionism	Eigen-Vector
Breach of agreements	6	8	1	8	5	0.603
Conflict in laws	0,25	1	0,125	1	0,5	0.055
Inappropriate contracting	1	4	0,16	4	2	0.181
Misinterpretation	0,5	2	0,2	2	1	0.104
Nationalism and local protectionism	0,25	1	0,125	1	0,5	0.055
Consistency Ratio (C.R) = 0.03032						

Likewise to table 34, the legal cluster for the Middle East in table 31 states that the highest eigen vector value of 0.384 is breach of agreements and the lowest eigen vector value of 0.108 is nationalism and local protectionism, conflict in laws and misinterpretation.

Table 34: Pairwise Comparison Regarding Legal Cluster for Middle East

	Breach of agreements	Conflict in laws	Inappropriate contracting	Misinterpretation	Nationalism and local protectionism	Eigen-Vector
Breach of agreements	2	3	1	3	3	0.384
Conflict in laws	0,33	1	0,33	1	1	0.108
Inappropriate contracting	1	3	0,5	3	3	0.288
Misinterpretation	0,33	1	0,33	1	1	0.108
Nationalism and local protectionism	0,33	1	0,33	1	1	0.108
Consistency Ratio (C.R) = 0.01308						

In table 35, the natural and environmental cluster for Europe indicates that unforeseen adverse site conditions has the highest eigen vector value of 0.422 and wind (storm) has the lowest eigen vector value of 0.087.

Table 35: Pairwise Comparison Regarding Natural&Environmental Cluster for the Europe

	Earthquake	Flood	Unforeseen adverse site conditions	Water pollution	Wind (storm)	Eigen-Vector
Earthquake	1	0,33	1	1	2	0.157
Flood	1	0,33	1	1	3	0.174
Unforeseen adverse site conditions	3	1	3	3	3	0.422
Water pollution	1	0,33	1	1	2	0.157
Wind (storm)	0,5	0,33	0,5	0,33	1	0.087
Consistency Ratio (C.R) = 0.02286						

According to the natural and environmental cluster for the Middle East in table 36, the highest eigen vector value of 0.355 is earthquake and the lowest eigen vector value of 0.087 is wind (storm).

Table 36: Pairwise Comparison Regarding Natural&Environmental Cluster for the Middle East

	Earthquake	Flood	Unforeseen adverse site conditions	Water pollution	Wind (storm)	Eigen-Vector
Earthquake	2	2	4	1	2	0.355
Flood	1	1	3	0,5	1	0.191
Unforeseen adverse site conditions	0,33	0,33	1	0,25	0,33	0.069
Water pollution	1	1	3	0,5	1	0.191
Wind (storm)	1	1	3	0,5	1	0.191
Consistency Ratio (C.R) = 0.00443						

In table 37, the political cluster for Europe states that the highest eigen vector value is 0.314 as changes of planning and the lowest eigen vector value is 0.079 as bribery.

Table 37: Pairwise Comparison Regarding Political Cluster for Europe

	Bribery	Changes of planning	Rigid bureaucracy	Unsupportive government policies	War and civil disorder	Eigen-Vector
Bribery	1	0,5	0,33	0,33	0,33	0.079
Changes of planning	3	3	1	2	1	0.314
Rigid bureaucracy	3	2	1	2	1	0.289
Unsupportive government policies	3	2	0,5	1	0,5	0.192
War and civil disorder	2	1	0,33	0,5	0,5	0.123
Consistency Ratio (C.R) = 0.02096						

In the political cluster for the Middle East, seen in table 38, the highest eigen vector value of 0.608 is war and civil disorder and the lowest eigen vector value of 0.050 is changes of planning and rigid bureaucracy.

Table 38: Pairwise Comparison Regarding Political Cluster for the Middle East

	Bribery	Changes of planning	Rigid bureaucracy	Unsupportive government policies	War and civil disorder	Eigen-Vector
Bribery	2	1	0,25	0,16	2	0.081
Changes of planning	1	0,5	0,2	0,14	1	0.050
Rigid bureaucracy	1	0,5	0,2	0,14	1	0.050
Unsupportive government policies	5	4	1	0,14	5	0.209
War and civil disorder	7	6	7	1	7	0.608
Consistency Ratio (C.R) = 0.08224						

In table 39, the categories cluster for Europe highlights that the highest eigen vector value of 0.372 is in financial risks and the lowest value of 0.056 is in technical risks.

On the other hand, similar to Europe, the highest eigen vector value for the Middle East in table 40 is 0.391 in financial risks but different from the lowest eigen vector value which is 0.028 in legal risks.

Table 39: Pairwise Comparison Regarding Categories Cluster for Europe

	1 construction risks	2 management risks	3 financial risks	4 technical risks	5 economic risks	6 legal risks	7 natural&environmental risks	8 political risks	Eigen-Vector
1 construction risks	1	2	0,33	3	2	5	1	3	0.159
2 management risks	0,5	1	0,33	2	1	5	1	2	0.111
3 financial risks	3	3	1	7	5	8	3	7	0.372
4 technical risks	0,33	0,5	0,14	1	1	2	0,33	1	0.056
5 economic risks	0,5	1	0,2	1	1	3	1	1	0.083
6 legal risks	0,2	0,2	0,125	0,5	0,33	1	0,2	0,5	0.029
7 natural&environmental risks	1	1	0,33	3	1	5	1	2	0.127
8 political risks	0,33	0,5	0,14	1	1	2	0,5	1	0.059
Consistency Ratio (C.R) = 0.01604									

Table 40: Pairwise Comparison Regarding Categories Cluster for Middle East

	1 construction risks	2 management risks	3 financial risks	4 technical risks	5 economic risks	6 legal risks	7 natural&environmental risks	8 political risks	Eigen-Vector
1 construction risks	1	3	0,25	4	2	5	1	3	0.166
2 management risks	0,33	1	0,25	2	1	5	1	2	0.099
3 financial risks	4	4	1	7	5	8	3	7	0.391
4 technical risks	0,25	0,5	0,14	1	1	2	0,33	1	0.052
5 economic risks	0,5	1	0,2	1	1	3	1	1	0.080
6 legal risks	0,2	0,2	0,125	0,5	0,33	1	0,2	0,5	0.028
7 natural&environmental risks	1	1	0,33	3	1	5	1	2	0.123
8 political risks	0,33	0,5	0,14	1	1	2	0,5	1	0.057
Consistency Ratio (C.R) = 0.02492									

After pairwise comparisons are made and consistency ratios are confirmed, the Super Decisions software is applied to achieve limit super matrix so as to obtain the risk factors in orders of priority. The limit super matrix which was attained separately for Europe and the Middle East are seen in Tables 41 and Table 42.

Table 41 and Table 42 present a section of the limit super matrix obtained by the ANP model. In Table 41, the most important risk factors for Europe can be considered as the change in scope of work in the construction cluster with an eigen vector value of 0.054793 as well as contractors' poor management ability with an eigen vector value of 0.040583 in the management cluster. Meanwhile, in the construction cluster for the Middle East, the highest eigen vector value in the construction cluster is 0.041356 as faulty techniques and loss of control with an eigen vector value of 0.042836 in the management cluster indicated in Table 42.

Table 41: A section of LSTIPs in Europe Limit Super Matrix

		1 construction risks					2 management risks				
		Change in scope of work	Cost escalation	Faulty construction techniques	Inadequate construction planning	Poor coordination among the consultants	Contractors' poor management ability	improper project feasibility and planning	Loss of control	Poor communications among stakeholders	Unrealistic scheduling
1 construction risks	Change in scope of work	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793
	Cost escalation	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300
	Faulty construction techniques	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350
	Inadequate construction planning	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300
	Poor coordination among the consultants	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360
2 management risks	Contractors' poor management ability	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583
	improper project feasibility and planning	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995
	Loss of control	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606
	Poor communications among stakeholders	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995
	Unrealistic scheduling	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034

Table 42: A section of LSTIPs in Middle East Limit Super Matrix

		1 construction risks					2 management risks				
		Change in scope of work	Cost escalation	Faulty construction techniques	Inadequate construction planning	Poor coordination among the consultants	Contractors' poor management ability	improper project feasibility and planning	Loss of control	Poor communications among stakeholders	Unrealistic scheduling
1 construction risks	Change in scope of work	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
	Cost escalation	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
	Faulty construction techniques	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
	Inadequate construction planning	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054
	Poor coordination among the consultants	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981
2 management risks	Contractors' poor management ability	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442
	improper project feasibility and planning	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961
	Loss of control	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836
	Poor communications among stakeholders	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848
	Unrealistic scheduling	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127

4.3.3 Discussion of Results

4.3.3.1 Comparison of European and the Middle Eastern Large-scale Transport Infrastructure Project Risk Factor Priorities

The results in Table 43 indicate that the primarily important risk factors in the European and Middle Eastern large-scale transport infrastructure projects are listed in the financial category. Note that the risk factors for both areas of study are arranged in the same order of significance. The first two important factors signifying the financial strength of the client and the financial failure of the contractor display the priority values of 11.54% and 11.10%, respectively, for the Middle East, and the priority values of 13.37% and 8.71%, respectively, for Europe. Today, the majority of large-scale projects are financed by clients. Moreover, contractors receive monthly payments from clients and are accountable for defraying subcontractors, construction materials sellers and others items of concern. As the financial power and robustness of the operating capital determine the durability of a company, comprehensive and professional strategic plans improve the application capacity (Gunhan and Arditi, 2005).

The third risk factor in Europe and the Middle East is the incomplete or inaccurate cost estimate. In Europe, the priority value for this risk is 8.59%, and in the Middle East, it is 7.87%. This risk factor is directly related to the work experience, knowledge and attitude of the designers, contractors/subcontractors and consultants. In this case, the recruitment of inexperienced individuals could lead to the occurrence of unforeseen risk factors in construction activities, causing deviation from the actual cost(Zouetal.,2014).

In the natural and environmental category for LSTIPs, the most important risk factors in the Middle East are not similar to those in Europe. The most significant risk factor in the Middle East, with a priority value of 4.55%, is noted as water pollution. Materials used in construction, such as paint, oil and cement, have a high possibility of blending with underground water and causing water pollution (Belayutham et al., 2016). In terms of Europe, water pollution is regarded as a less hazardous risk factor compared to the Middle East. The most important risk factor under the natural and environmental category for Europe is floods, with a priority value of 5.40%. In spite of the advancements, the construction sector is insufficient in flood risk management. Unfortunately, many projects have been implemented, regardless of considering data on the geological and hydrological structure of the construction site (the depth and intensity of a flood, etc.), the possibilities of the cause of natural or environmental disasters, and their effects. Thus, the outcome may lead to permanent and costly problems (Feyen et al., 2011).

The management category presents different priority risk factors for both regions. The most significant risk factor for the Middle East is loss of control with a priority value of 4.28%. Inefficiency, resulting in loss of control, is caused by the complicacy, ambiguity, inadequacy of communication, coordination and integration, as well as the individuals' lack of responsibility and potential in projects (Tuuli et al., 2010). In Europe, the most important risk factor in the management category indicates the contractor's poor management ability, with a priority value of 4.06%. The lack of the contractor's management skills could jeopardize safety conditions and negatively affect the cost and duration of a project (Zou et al., 2007).

With the priority values of 5.48% and 4.14%, it is clearly seen that Europe and the Middle East give primary importance to the change in scope of work risk factor listed in the construction category. It is inevitable during the course of a project that alterations in the finalized scope of the project bring about complications and unforeseen problems (increase in cost, delays in schedule, etc.) (Project Management Institute, 2000).

In the political risk category, the main risk factor for the Middle East is unsupportive government policies, having a priority value of 3.62%. Currently, in the project implementation phase, unsupportive government policies overburden the construction sector. The lack of funds to pay contractors leads to inflation and failure of the construction sector. As a result, the country may be dragged towards a major decline in the economy (Birgonul and Ozdoğan, 2000). In contrast to the Middle East, Europe gives less emphasis to this matter and more importance to the rigid bureaucracy risk factor, with a priority value of 1.87%.

Increased materials cost, having a priority value of 2.91%, is the most significant risk factor under the economic category in the Middle East. With the rising inflation, the cost of construction materials increases, thus causing cost overruns (Kaming et al., 2010). This situation differs in Europe, where resource availability has a greater importance, with a priority value of 2.76% in the economic category. All stakeholders involved may be the cause of delays in the project fulfilment process mainly because of the lack of resources available (Assaf and Heiji, 2005).

Both Europe and the Middle East give major importance to the poor definition of scope risk factor in the technical risk category; the Middle East has noted a priority value of 2.33% and Europe has noted a priority value of 2.18% for this risk factor. To date, experiences regarding the factor of poor definition of scope in many construction sectors show that the main reasons for project failures are the negative effect this factor has on cost and time (Cho and Gibson, 2001).

In terms of the legal risk category, the primary risk factor for both Europe and the Middle East is inappropriate contracting. The priority value for this risk factor was identified as 1.79% for the Middle East and 1.14% for Europe. A contract is known as an agreement among two or more parties that is comprised of elements based on laws (Hendrickson, 2010). Conflicts among clients and contractors may turn the project into a win-lose or vice versa situation. According to Kwawu and Hughes (2005), the most salient cause of the failure of a project is inappropriate contracting.

Consequently, the results obtained in this study indicate that LSTIPs in Europe and the Middle East have both common and different risk factors. In addition, the orders of priority display the risk factors that could occur in European and the Middle Eastern large-scale infrastructure projects, shedding light on the planning stage of a project.

Table 43: Comparison of European and the Middle Eastern LSTIP Risk Priorities

Europe risk priorities			Middle East risk priorities		
Risk category	Risk factor	Priority (%)	Risk category	Risk factor	Priority (%)
Financial	Financial strength of client	13.37	Financial	Financial strength of client	11.54
Financial	Financial failure of contractor	8.71	Financial	Financial failure of contractor	11.10
Financial	Incomplete or inaccurate cost estimate	8.59	Financial	Incomplete or inaccurate cost estimate	7.87
Construction	Change in scope of work	5.48	Natural&Environmental	Water pollution	4.55
Natural&Environmental	Flood	5.40	Financial	Inadequate site information	4.34
Management	Contractors' poor management ability	4.06	Management	Loss of control	4.28
Financial	Inadequate site information	3.36	Management	Contractors' poor management ability	4.14
Construction	Inadequate construction planning	3.33	Construction	Change in scope of work	4.14
Construction	Cost escalation	3.33	Construction	Cost escalation	4.14
Financial	Design variations	3.19	Construction	Faulty construction techniques	4.14
Economic	Resources availability	2.76	Political	Unsupportive government policies	3.62
Economic	Increased materials cost	2.76	Economic	Increased materials cost	2.91
Management	Loss of control	2.66	Economic	Resources availability	2.81
Natural&Environmental	Water pollution	2.24	Natural&Environmental	Earthquake	2.45
Construction	Poor coordination among the consultants	2.24	Natural&Environmental	Flood	2.45
Technical	Poor definition of scope	2.18	Natural&Environmental	Wind (storm)	2.45
Natural&Environmental	Unforeseen adverse site conditions	2.02	Financial	Design variations	2.37
Natural&Environmental	Earthquake	2.02	Technical	Poor definition of scope	2.33
Management	Unrealistic scheduling	2.00	Construction	Poor coordination among the consultants	2.20
Political	Rigid bureaucracy	1.87	Legal	Inappropriate contracting	1.79
Political	War and civil disorder	1.72	Construction	Inadequate construction planning	1.31
Technical	Employment of inexperienced designers	1.63	Economic	Economic crisis	1.29
Construction	Faulty construction techniques	1.54	Technical	Employment of inexperienced designers	1.25
Management	Poor communications among stakeholders	1.20	Technical	Material suitability and accessibility and shortage	1.25
Management	improper project feasibility and planning	1.20	Political	Rigid bureaucracy	1.25
Political	Unsupportive government policies	1.15	Management	improper project feasibility and planning	1.00
Legal	Inappropriate contracting	1.14	Management	Poor communications among stakeholders	0.98
Natural&Environmental	Wind (storm)	1.11	Natural&Environmental	Unforeseen adverse site conditions	0.89
Economic	Exchange rates fluctuation	1.06	Economic	Exchange rates fluctuation	0.87
Economic	Economic crisis	1.06	Management	Unrealistic scheduling	0.71
Legal	Breach of agreements	0.86	Legal	Breach of agreements	0.53
Political	Changes of planning	0.73	Economic	Inflation	0.49
Economic	Inflation	0.71	Political	Changes of planning	0.48
Technical	Material suitability and accessibility and shortage	0.63	Technical	Inadequate time allocation	0.42
Technical	Insufficient or incorrect design information	0.62	Technical	Insufficient or incorrect design information	0.42
Technical	Inadequate time allocation	0.62	Legal	Nationalism and local protectionism	0.32
Political	Bribery	0.48	Political	Bribery	0.31
Legal	Nationalism and local protectionism	0.32	Political	War and civil disorder	0.30
Legal	Misinterpretation	0.32	Legal	Conflict in laws	0.16
Legal	Conflict in laws	0.32	Legal	Misinterpretation	0.16

4.4 Testing the Results of Proposed ANP Model

4.4.1 Tunnel Project in Middle East

4.4.1.1 Contractor Company Background

The company, originating from Turkey, was established in 1965 and is currently active in the production of projects in the area of large-scale transport infrastructure. The company is comprised of approximately 4000 employees and has more than one office in the Middle East. In 2017, the company had reached a construction capacity of 42 million square metres by having contracts for a 39 rail lines system (rail-way, subway), 300 stations and multiple tunnel projects in three continents.

4.4.1.2 Project Details

The tunnel was constructed to interconnect the European side of Istanbul to its Asian side. The tunnel is an LSTIP built under the Bosphorus of 5.4 km in length and a total of 14.6 km in length with the connection paths. The tunnel is three stories high, with the first and third floors constructed for motor vehicles and the second floor constructed for a rail system. The construction of the project, having a total cost of 1.2 billion dollars, began in 2011 and was completed and opened to service in 2016.

4.4.1.3 The Risks Confronted in the Tunnel Project

First, a large bank loan was acquired because the complete amount of investment required for the project could not be supplied by the project owner. Furthermore, the sea was contaminated with waste during the construction phase and the tunnel ventilation pipes were installed very low, thus spreading gas to the air and sea. Moreover, as a result of the evaluation conducted by the government, a few changes weremadeduring the construction period For example, the buildings consisting of technical equipment were relocated and intersections were expanded. In addition, the project, which began in 2011, faced a cost overrun due to the increase in material prices caused by the soaring inflation between the years 2015 and 2016. The project has more than 2000 experienced employees that are qualified in work health and safety; therefore, risks were not confronted in the management and technical areas. Although there were minor conflicts between the contractor and project owner in the beginning, they were resolved over time.

In general terms, the project confronted numerous risks, whereas it faced no problems in a few areas. Table 44 displays the risk factors that occurred during the construction phase, with their categories and the risk priority order sequenced from most important to least important.

Table 44: The Order of Priority According to the Risks and Factors Confronted in Tunnel Projects

Risk category	**Risk factor**
Financial	Financial strength of client
Natural & Environmental	Water pollution, air pollution
Management	No problem
Construction	Change in scope of work
Political	No problem
Economic	Increased materials cost
Technical	No problem
Legal	Inappropriate contracting

4.4.2 Railway Project in Europe

4.4.2.1 Contractor Company Background

The company, established in the United States in 1898, is actively operating in 160 different countries and has fulfilled numerous LSTIPs. The company holds offices in 30 countries and has approximately 53100 employees. In 2016, it owned a net income of 33 billion dollars and has been involved in many important projects to date.

4.4.2.2 Project Details

The LSTIP, constructed in the United Kingdom, is a total of 42 km in length. This central rail tunnel was built to provide transportation among various areas of London and the Home Counties of Berkshire, Essex and Buckinghamshire. The project began in 2009, with an estimated project cost of 14.6 billion pounds, and is expected to be completed and brought into service at the end of 2018.

4.4.2.3 Risks Confronted in the Railway Project

Although the project owner could afford the majority of the project cost, the remaining fund of the project was financed by two additional institutions and the government. Furthermore, because elements such as weather conditions and climate change were not included in the scope of the project, the flood risk increased in the project. A qualified management team was available in the company; however, a certain amount of change was made in the scope of the project because it was found to be insufficient. Because this ongoing project is not proceeding in accordance to the specified timeline, the estimated cost has been exceeded. Based on the agreements made between the government and the companies in advance, it was guaranteed that the income obtained from the LSTIP would compensate the preprovided investment within a short period of time. Thus, issues were not faced with the government in political terms.

Overall, in this railway project, some risks were encountered during the construction stage, whereas other risks were not. Table 45 shows the risks that were and were not confronted, their categories and their orders of priority, arranged from the most important to the least important.

Table 45: The Order of Priority According to Risks and Factors Confronted in the Rail-way Project

Risk category	Risk factor
Financial	Financial strength of client
Construction	Change in scope of work
Natural & Environmental	Flood
Management	No problem
Economic	Resource availability
Technical	Poor scope of definition
Political	No problem
Legal	No problem

4.4.3 Results of Case Studies

In consideration of today's conditions in the Middle East, because numerous firms experience difficulties in the financial area, the obtained results support one another. On the other hand, as the water pollution risk indicates, problems occur in the natural and environmental area in the Middle East because many subcontractors and utilities are not able to fulfill the project properly or abandon construction sites. In addition, the change in scope of work risk in the construction of the tunnel project reveals that a deep wound has been inflicted on LSTIPs in the Middle East, resulting in cost overruns and time loss in the project. Moreover, the inflation rates, taxes and the continuous change of exchange rates in the present days of Middle East are leading to an increase in material prices in economic sense and this is clearly verified by the obtained risk factor. On the other hand, the risk factor in legal terms highlights that in the process of creating specifications, misinterpretation can emerge due to incomplete information or inadequate observations when converting into contracts. As a result, this situation is generally finalized at court for both parties. In the Middle East, a lot of administrative problems will likely arise in today's LSTIPs, however, no single risk has been confronted in the management area in the tunnel project. In fact, such problems are not encountered in the tunnel project even though there are multiple political problems in LSTIPs in the Middle East. Likewise, no risks have been detected in the technical field, despite the fact that many technical problems are encountered in LSTIPs due to the lack of qualified personnel in Middle Eastern LSTIPs.

In today's conditions for Europe, even though no problems are encountered in the financial area of LSTIPs, one risk has been faced in the financial field in the railway project. On the other hand, in almost every LSTIP in Europe, a lot of scope alterations are made during the construction, which coincides with the result. Resource availability risk has been confronted in the railway project, while no problem is expected in the economic area since a resource allocated to the LSTIPs in Europe is reserved. Moreover, many LSTIPs in Europe have recruited their employees according to their experience, and at the same time, have their personnel subjected to the training courses, and while there is no expectation of any problem to arise in the technical area, there is a risk of poor scope definition in the railway project. It is also clearly visible that because there is strict coordination in LSTIPs in Europe, no problems have occurred in the management area. Similarly, supporting the European political arena of LSTIPs and legally adhering to all kinds of rules and regulations correspond to the fact that no problems have been confronted in the two areas of the railway project.

Regarding the results of the railway project in Europe, the primary problems experienced in the financial, construction, natural and environmental, economic and technical areas correspond to risk factors and priority orders of Europe obtained with the ANP model. Similarly, the issues occurring in the financial, natural and environmental, construction, technical and legal categories in the Middle East tunnel project are in line with the Middle Eastern risk factors and priority orders determined via the ANP model.

Chapter 5

CONCEPTUAL FRAMEWORK: THE APPLICABILITY OF THE ANP MODEL AND KNOWLEDGE-BASED RISK IDENTIFICATION AND DECISION SUPPORT TOOL FOR LSTIPS

5.1 Introduction

A conceptual framework is a description of a phenomenon based on the synthesis of literature. Moreover, Maxwell (1996) defines it as "the system of concepts, assumptions, expectations, beliefs and theories that supports and informs your research". A conceptual framework organizes the structure of a research regarding observations in the study area as well as other researcher's perspectives. The concepts or ideas provide a context for understanding and explaining findings of various studies. This way, coherence and explicitness is established in the research process. On the other hand, applicability refers to how accurate the results of a review, study or observation are in the practice environment.

The work of human expertise can be performed by an expert system that allows a computer software program to carry out the tasks (Rada, 2008). According to Klein and Methlie (1995), expert systems should be regarded as computer programs that display an experts' knowledge and inference process to unravel complicated problems, presenting the possible solutions and recommendations in identifying risks and making decisions.

In this section, a conceptual framework was developed as a guide for the planning phase of firms that will operate in future LSTIPs in two of the regions according to the analysis results of risks that could arise in European and Middle Eastern LSTIPs (4^{th} section). Furthermore, in section 4 of this study, the applicability of the ANP on risks was tested. Finally, by using the risk factors' priority orders obtained from the ANP model as well as data gathered from firms, a tool is developed and implemented for faster and more efficient risk identification and decision making against risks.

5.2 Testing the Applicability of ANP Model and Results

Firms operating in the area of LSTIPs in Europe and the Middle East were contacted and distributed a questionnaire that comprised of questions about the utility and applicability of ANP model in improving risks. In Europe, a total of 116 firms out of 182 and in the Middle East, a total of 105 firms out of 165 completed the questionnaire. Firms showed strong interest and gave a considerable amount of support in the questionnaire. Participants evaluated to what degree the risk factors emerging from LSTIPs could be improved via ANP model and its results. The evaluation was carried out on a rating scale ranging from 1 (poor) to 5 (excellent). The results are significant as it clearly shows that participants believe that the ANP model could highly improve risks that may arise in LSTIPs.

According to the results obtained from the European firms' questionnaires in Table 46, the risk categories that the ANP model would be most beneficial for is ordered from largest to smallest in mean rating values as: financial risk (4.03), construction risk (3.98), natural and environmental risk (3.82), managerial risk (3.63), economic risk (3.60), technical risk (3.54), political risk (3.45) and legal risk (3.42).

Table 46: Responses to LSTIPs-based ANP Model for European Region

		Rating (%)					
Number	**Evaluation questions**	**1: Poor**	**2: Fair**	**3: Satisfactory**	**4: Good**	**5: Excellent**	**Mean Rating**
1	To what extent can ANP Model help to assess Construction Risks?	-	-	38	42	36	3.98
2	To what extent can ANP Model help to assess Financial Risks?	-	-	39	34	43	4.03
3	To what extent can ANP Model help to assess Managerial Risks?	-	23	28	34	31	3.63
4	To what extent can ANP Model help to assess Technical Risks?	-	24	31	35	26	3.54
5	To what extent can ANP Model help to assess Economic Risks?	-	24	29	32	31	3.60
6	To what extent can ANP Model help to assess Legal Risks?	-	25	37	34	20	3.42
7	To what extent can ANP Model help to assess Natural and Environmental Risks?	-	16	27	35	38	3.82
8	To what extent can ANP Model help to assess Political Risks?	-	25	34	37	20	3.45
9	How easy is it to follow the ANP Model?	-	-	31	44	41	4.09
10	How useful do you consider the overall ANP Model?	-	-	32	48	36	4.03

Based on the views of the firms in Europe, the significance values of the factors obtained in the ANP model, as indicated in the results in Table 46, ordered from the highest value to the lowest as financial, construction, natural and environmental, managerial, economic, technical, political and legal categories, by considering LSTIPs in the planning phase and taking precautions, projects could be fulfilled with accuracy, clarity, less harm and loss, no arguments and within a shorter period of time.

According to the results obtained from the Middle Eastern firms' questionnaires in Table 47, the risk categories that the ANP model would be most beneficial for is ordered from largest to smallest in mean rating values as: Financial risk (4.12), Managerial risk (3.94), Construction risk (3.90), Natural and Environmental risk (3.74), Economic risk (3.43), Legal risk (3.22), Political risk (3.09) and Technical risk (3.08).

Table 47: Responses to LSTIPs-based ANP Model for Middle Eastern Region

		Rating (%)					
Number	**Evaluation questions**	**1: Poor**	**2: Fair**	**3: Satisfactory**	**4: Good**	**5: Excellent**	**Mean Rating**
1	To what extent can ANP Model help to assess Construction Risks?	-	-	37	41	27	3.90
2	To what extent can ANP Model help to assess Financial Risks?	-	-	28	36	41	4.12
3	To what extent can ANP Model help to assess Managerial Risks?	-	-	36	39	30	3.94
4	To what extent can ANP Model help to assess Technical Risks?	-	23	26	34	22	3.08
5	To what extent can ANP Model help to assess Economic Risks?	-	19	28	35	23	3.43
6	To what extent can ANP Model help to assess Legal Risks?	-	20	35	31	19	3.22
7	To what extent can ANP Model help to assess Natural and Environmental Risks?	-	7	23	36	39	3.74
8	To what extent can ANP Model help to assess Political Risks?	-	16	26	32	31	3.09
9	How easy is it to follow the ANP Model?	-	-	27	40	38	4.14
10	How useful do you consider the overall ANP Model?	-	-	25	45	35	4.09

According to the views of the firms in Europe, the significance values of the factors obtained in the ANP model, as illustrated in the results in table 47, ordered from the highest value to the lowest as financial, managerial, construction, natural and environmental, economic, legal, political and technical categories, by considering

LSTIPs in the planning phase and taking precautions, projects could be fulfilled with accuracy, clarity, less harm and loss, no arguments and within a shorter period of time.

In conclusion, when the results from the evaluation of the 9th and 10th question in the questionnaire are analysed, the values for Europe, 4.09 and 4.03, as well as the values for the Middle East, 4.14 and 4.09, clearly indicate that the ANP model is not complicated and is in fact rather beneficial. Moreover, the results from Table 46 and Table 47 (responses from the questionnaires conducted in European and Middle Eastern firms) and Table 43 (risk priority orders of LSTIPs) are complementary and supportive to one another. This means that the ANP model is applicable in these types of projects in both regions.

5.3 Expert System Tool: LSTIPs RiDECS

5.3.1 Defining the Variables

When developing the proposed tool, the steps required to be taken are described below. This LSTIPs RiDECS tool is developed to support users in the decision-making phases by being comprehensible in the design and rule creation of the system and by being a facilitative structure for users.

The variables loaded on the expert system shell are defined primarily by means of the add data and edit sections located in the expert system shell development tool as seen in Figure 19. Figure 20 displays a list of the defined variables which are located on the left.

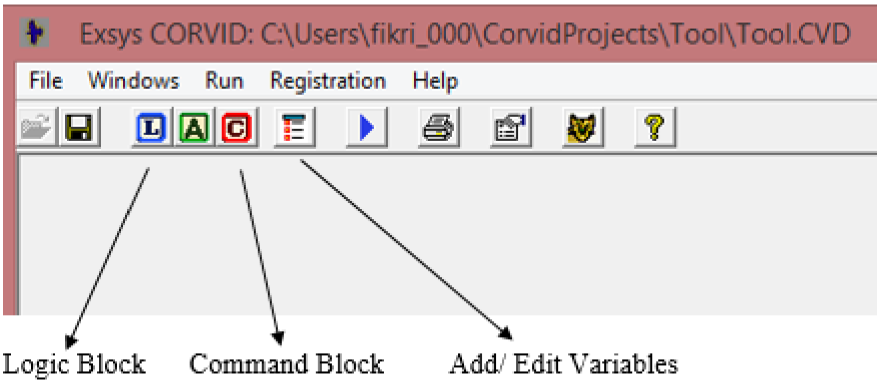

Figure 19: An Overview of the EXSYS CORVID Application

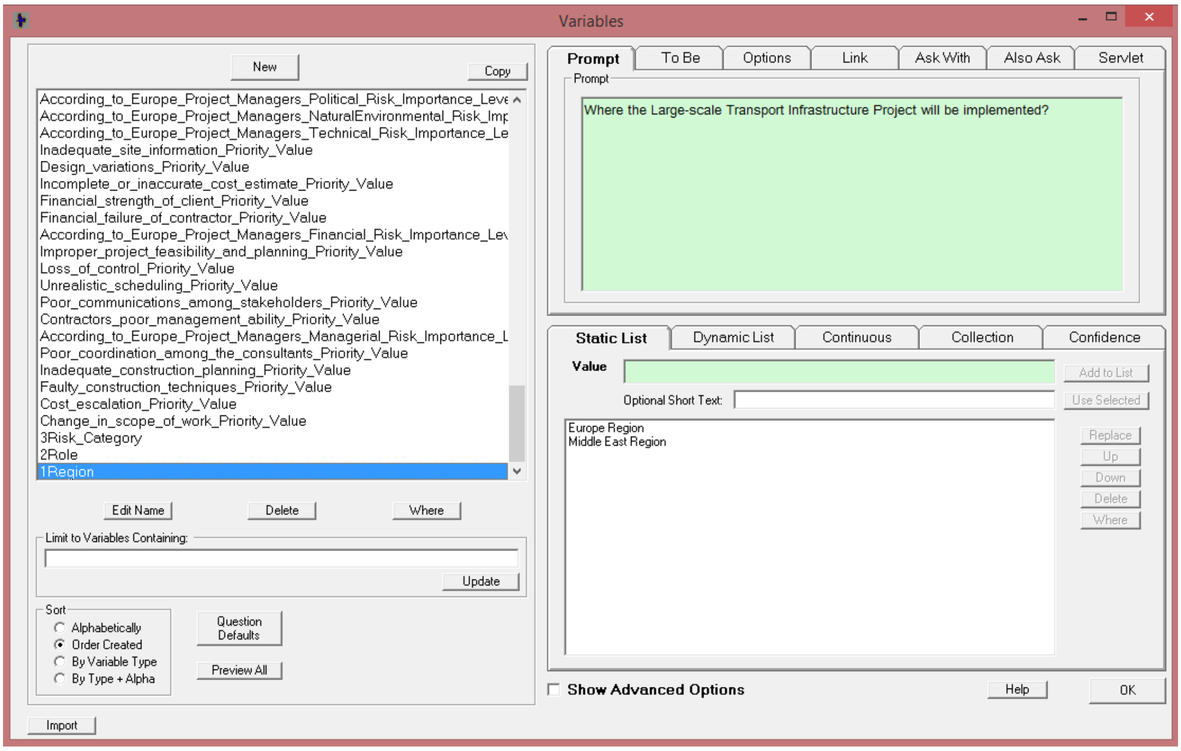

Figure 20: Definition of the Variables

5.3.2 Defining the Logic Block and Command Block

After the variables are defined, the rule conversion process is applied through the logic block, the most important feature in the system. As seen in Figure 21, the decision of the user could be easily tracked from the logic block. In this application, the user has selected Europe as the LSTIP region from the first question directed. In the second question, contracting firm has been chosen as the firm type. Following these questions, the role of the project has been selected as project manager and the type of project as tunnel project.

In the final part, considering the expected results, the user has specified the levels of the risk factors as well as the categories of the risks that he is interested in. In this phase, the user has obtained the desired result by selecting the level of risk factors as high and the category as managerial.

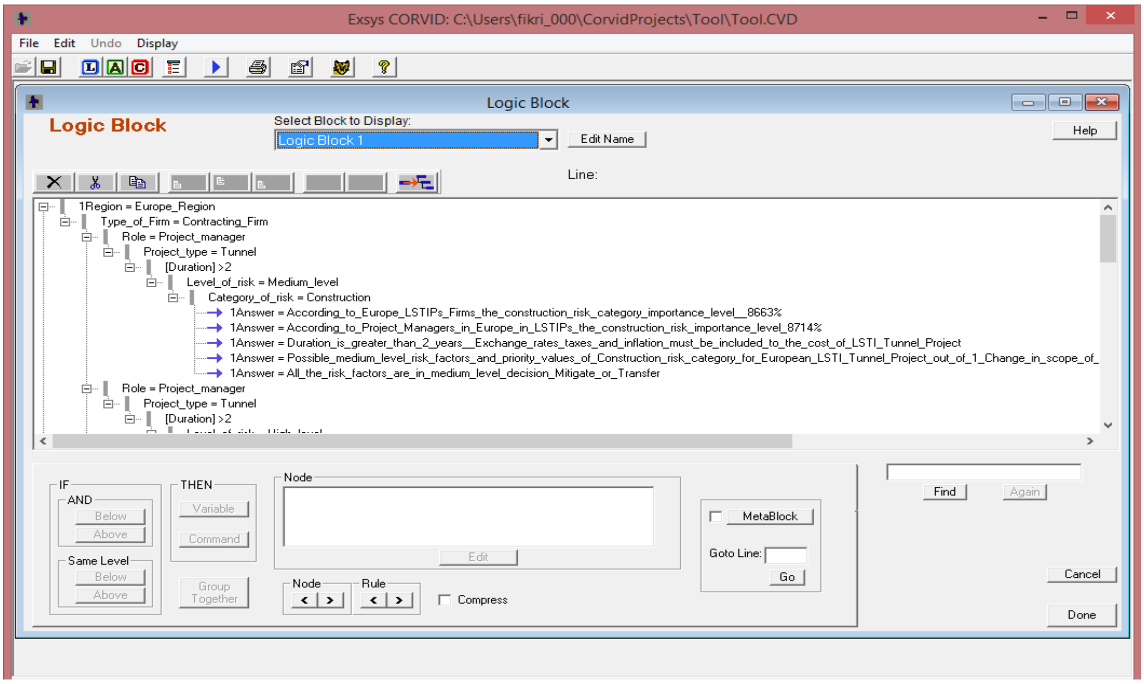

Figure 21: The creation of the rules in the logic block

Figure 22 illustrates all the rules preferred by the user from the rules cluster found in the logic block.

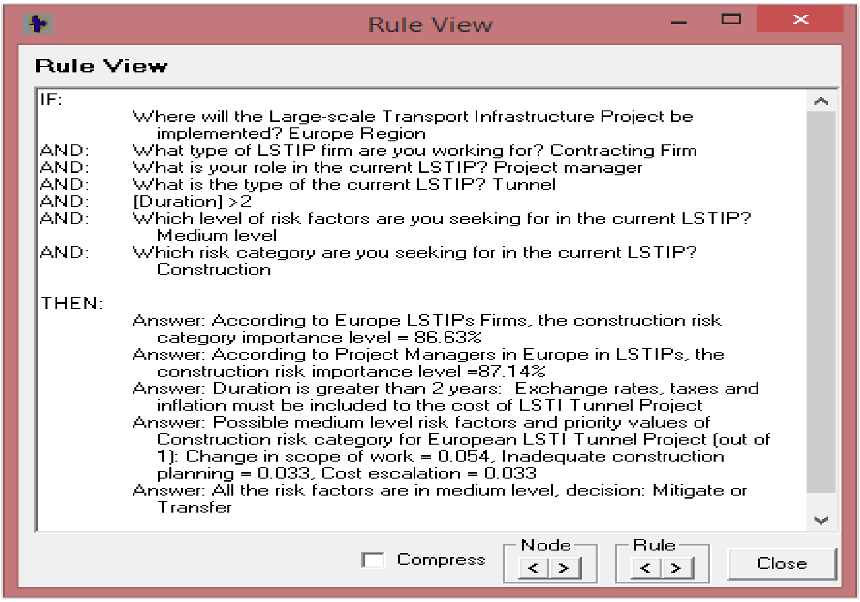

Figure 22: An overview of the rules cluster selected for the application

5.3.3 The Outcomes of the Proposed Expert System Application

The outcomes of the LSTIPs RiDECS tool application that is thought to be beneficial in supporting decision making in risk identification and risk confrontation during the planning phase of LSTIPs in Europe is displayed in steps below in Figure 23-31.

The developed risk identification and decision supporting tool, as displayed in Figure 23, describes the aim of the tool, the name of the programme, the start button, the introduction page and presents photographs of the areas used.

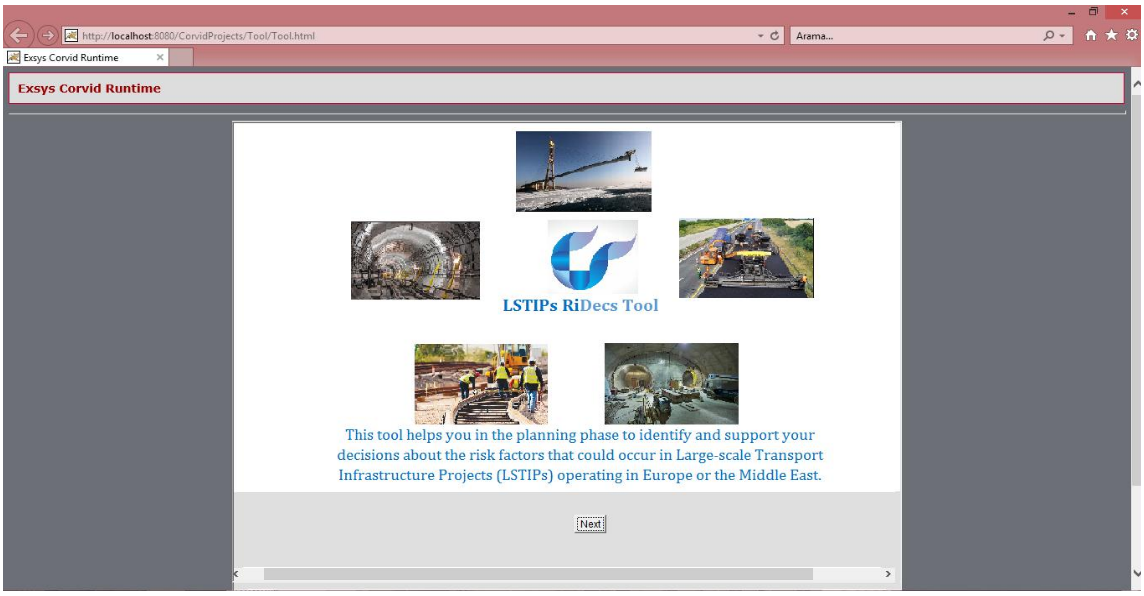

Figure 23: Representation of the Introduction Page of the Proposed Expert System

Figure 24 shows that there are two different types of regions where the users have worked at; Europe and the Middle East. In this section, the user has selected the European region as a response.

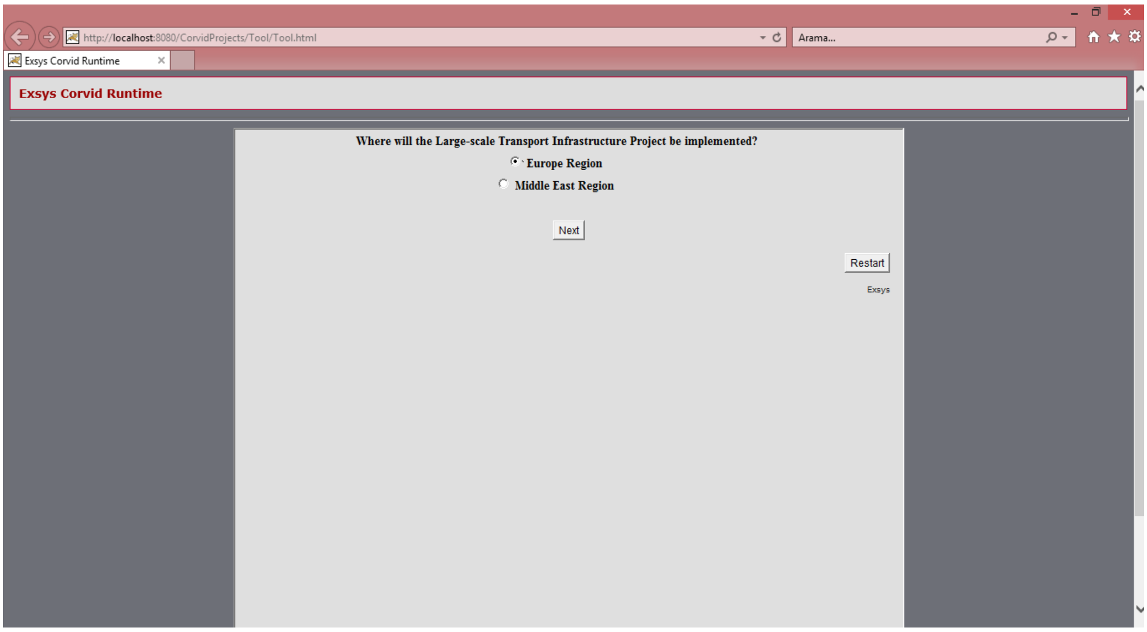

Figure 24: The Function of the Decision Mechanism (Europe Region Selection)

As seen in Figure 25, the tool asks the user to select the type of firm he is currently working for; contracting firm or engineering consulting firm. Here, the user has selected the contracting firm.

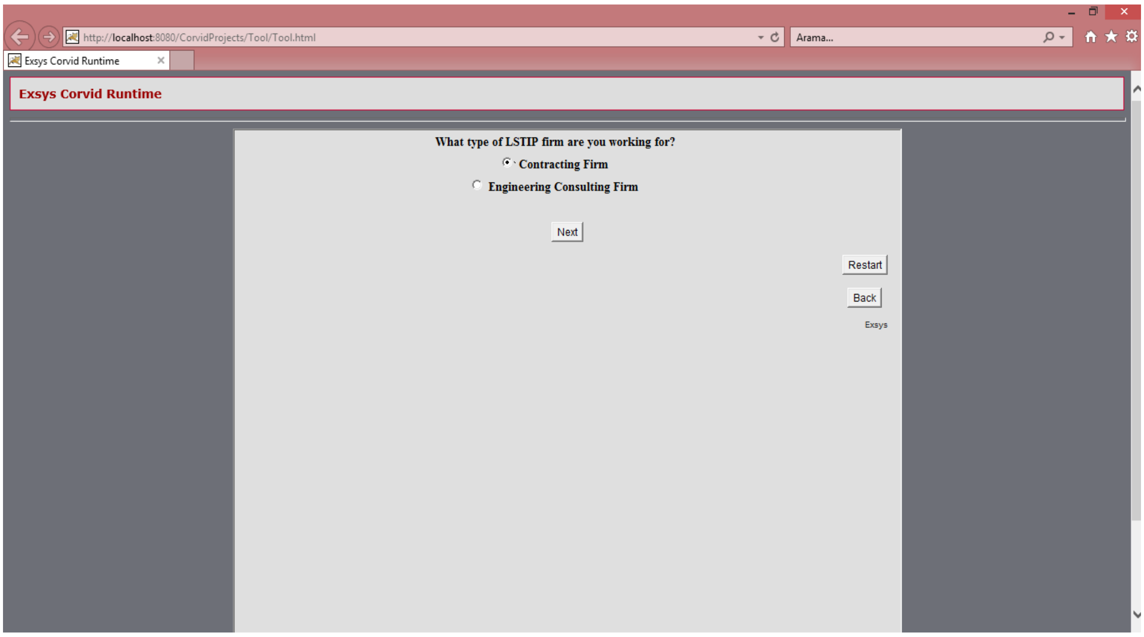

Figure 25: The Function of the Decision Mechanism (Firm Selection for Europe)

In Figure 26, the role of the user who is currently working at a contracting firm in LSTIPs is requested. Two roles are given as options; project manager and construction manager. Here, the user has selected project manager.

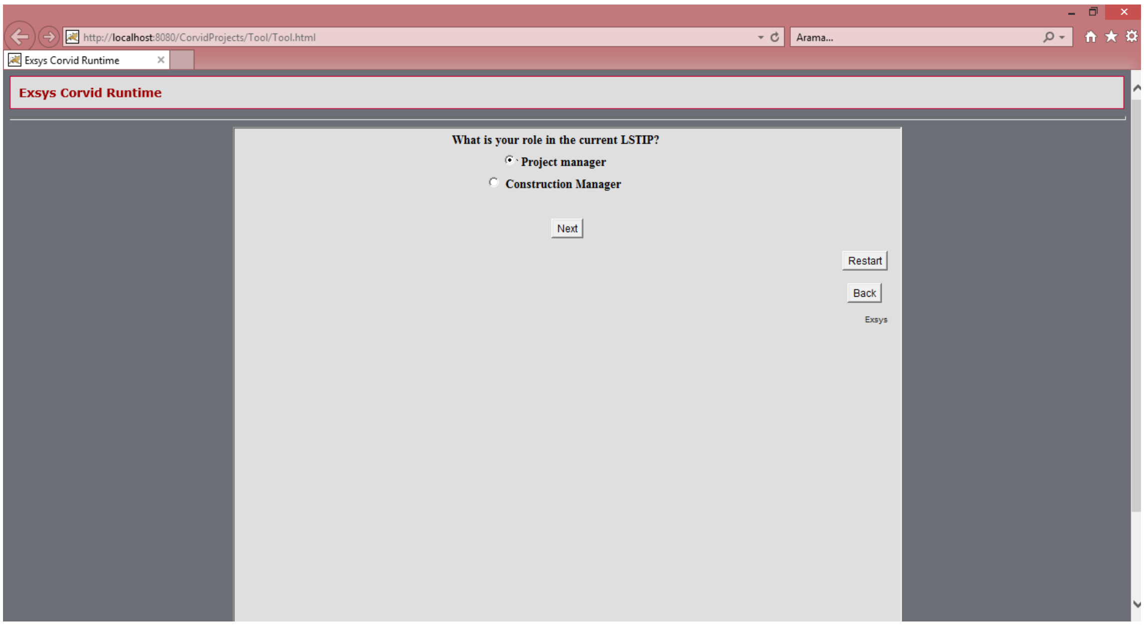

Figure 26: The function of the Decision Mechanism (Role Selection for Europe)

In Figure 27, the tool has required information about the type of project the user has worked in; tunnel, bridge, highway, railway and subway. In this example, the user has chosen tunnel project.

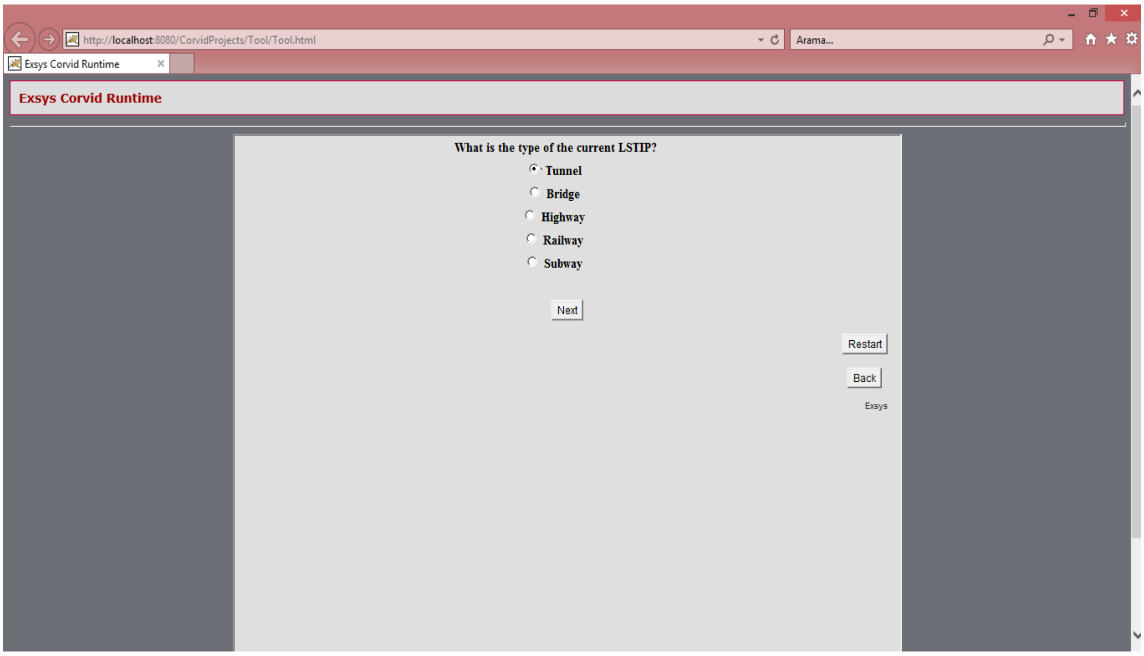

Figure 27: The Function of the Decision Mechanism (Project type selection for Europe)

In figure 28, the tool asks the user to state the duration of the LSTIP they are currently working for. Here, the user has typed three years (in numerical form) in the provided space.

Figure 28: The Function of the Decision Mechanism (Stating the Project Duration for Europe)

In figure 29, the user is asked to indicate the level of the risk factors that could occur in the current project. Three levels are provided as options; high, medium and low. In this section, the user has responded as medium level.

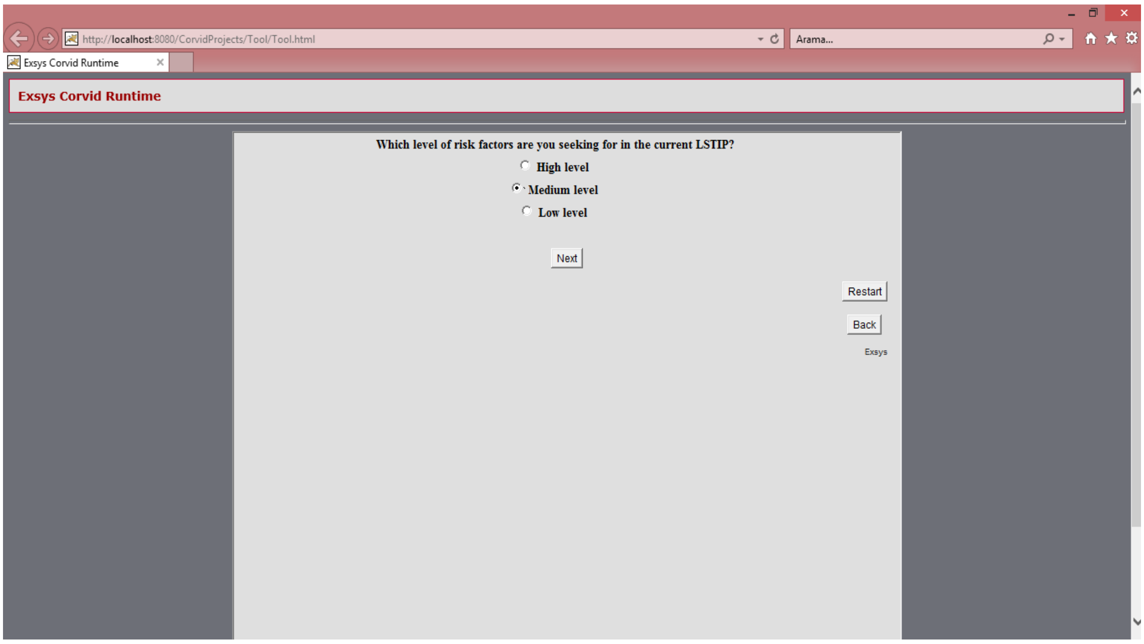

Figure 29: The Function of the Decision Mechanism (The Selection of the Importance Level of the Risk Factors for Europe)

In figure 30, based on the current project, the proposed tool asks the user to decide which category of risks he would like to learn. The options range from specific areas (construction to political) to the selection of all at once. In this example, the user has chosen the construction option out of all categories.

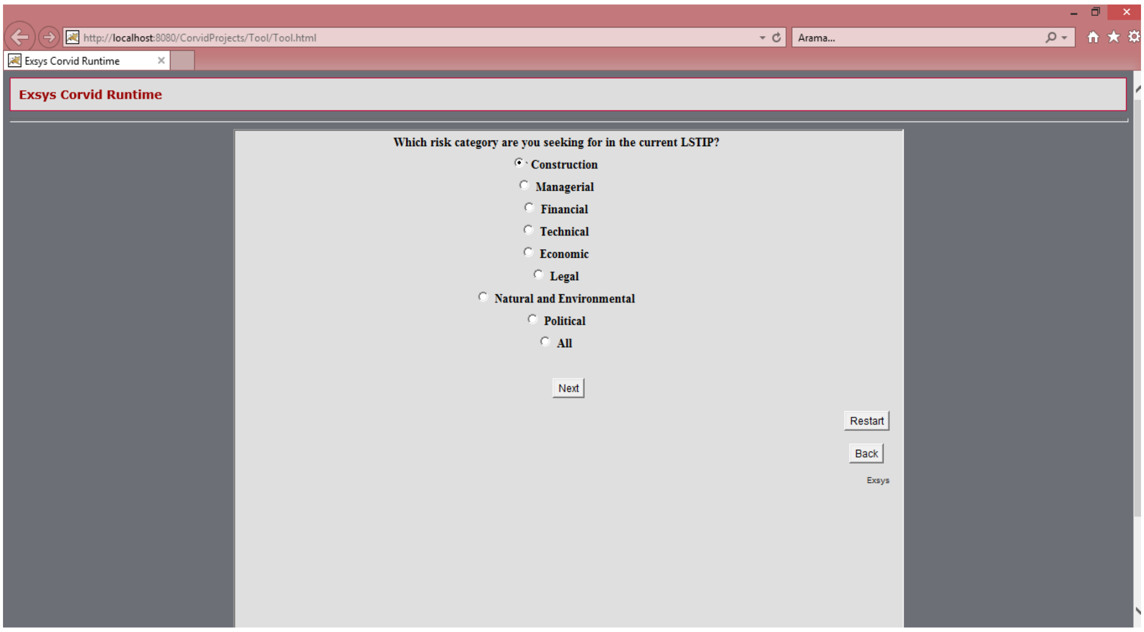

Figure 30: The Function of the Decision Mechanism (The Selection of the Risk Category for Europe)

Figure 31 displays all of the selections made by the user in an orderly manner; the region, the type of firm, the role of user, type of the project, the duration of the project, the level of the risks and all the choices made for the categories. As a result of the selected options in LSTIPs RiDECS tool, the tool has stated the importance level of the construction category according to Europe, the importance level of the construction category according to the project managers in Europe, the economic measures that should be taken depending on the project process, the medium level risk factors that could occur under the construction category as well as their significance values and the decision to be taken against possible risk factors.

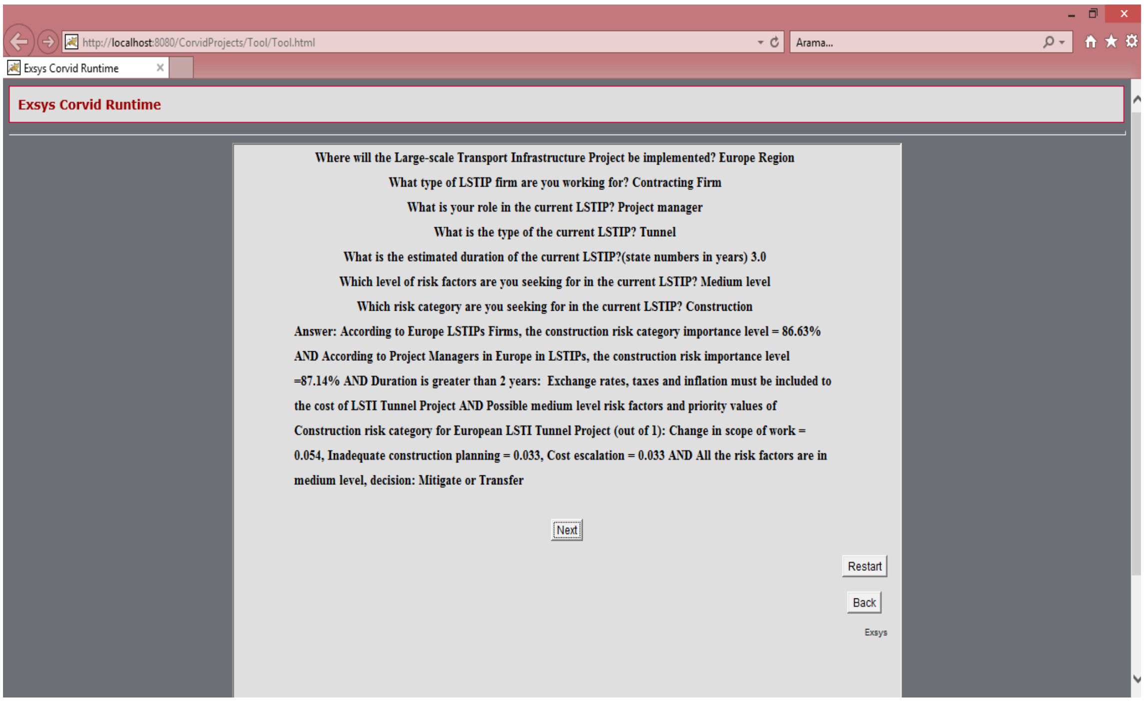

Figure 31: The Results Obtained According to the User's Selections for Europe

The outcomes of the expert system application that is thought to be beneficial in supporting decision making in risk identification and risk confrontation during the planning phase of LSTIPs in the Middle East is also displayed in steps below in Figure 32-39.

Figure 32 presents two different types of regions where the users have worked at; Europe and the Middle East. In this section, the user has selected the Middle East region as a response.

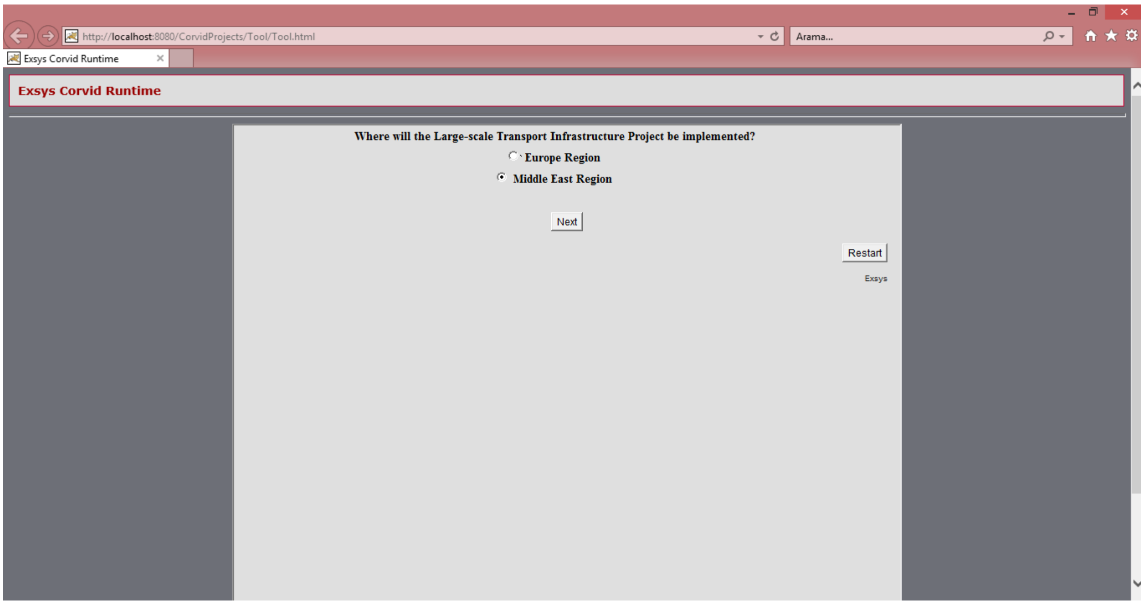

Figure 32: The Function of the Decision Mechanism (the Middle East Region Selection)

As illustrated in figure 33, the tool asks the user to select the type of firm he is currently working for; contracting firm or engineering consulting firm. Here, the user has selected the contracting firm.

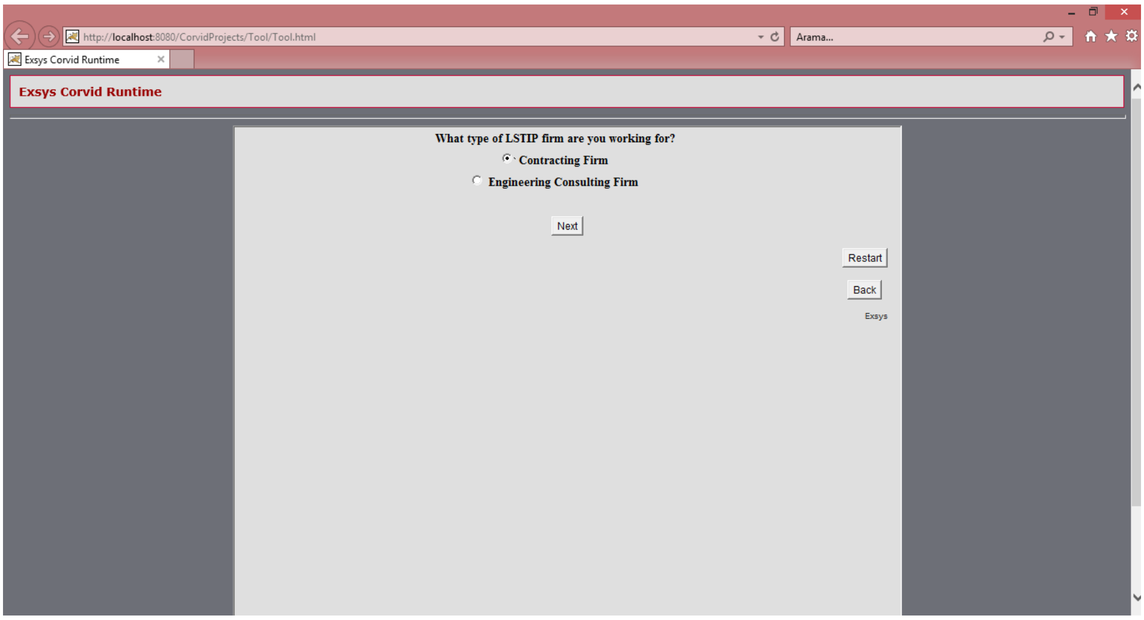

Figure 33: The Function of the Decision Mechanism (Firm Selection for the Middle East)

In figure 34, the role of the user who is currently working at a contracting firm in LSTIPs is requested. Two roles are given as options; project manager and construction manager. In this example, the user has selected construction manager.

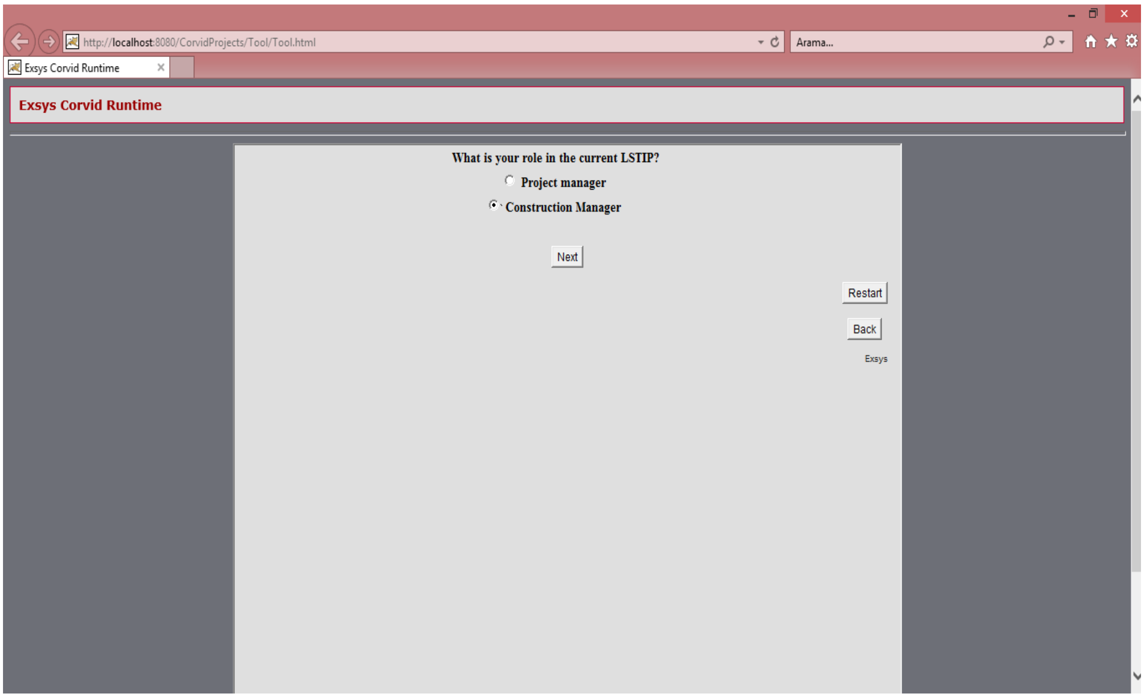

Figure 34: The Function of the Decision Mechanism (Role Selection for the Middle East)

In figure 35, the tool has required information about the type of project the user has worked in; tunnel, bridge, highway, railway and subway. In this example, the user has selected bridge project.

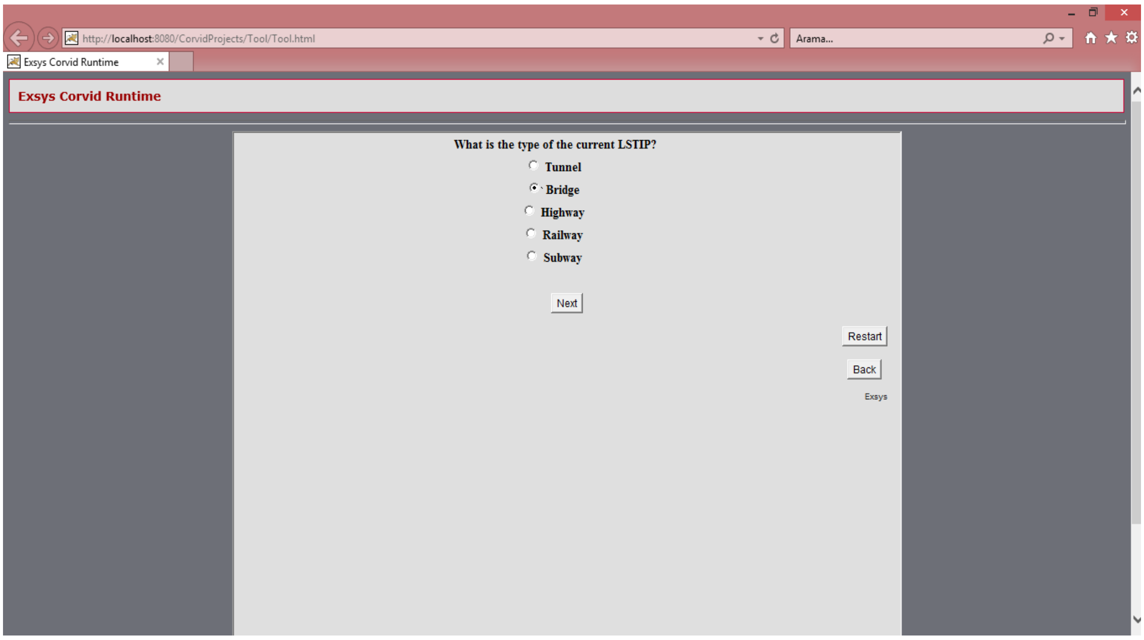

Figure 35: The Function of the Decision Mechanism (Project Type Selection for the Middle East)

In figure 36, the tool asks the user to state the duration of the LSTIP they are currently working for. Here, the user has typed four years (in numerical form) in the provided space.

Figure 36: The Function of the Decision Mechanism (Stating the Project Duration for the Middle East)

In figure 37, the user is asked to indicate the level of the risk factors that could occur in the current project. Three levels are provided as options; high, medium and low. In this section, the user has selected high level.

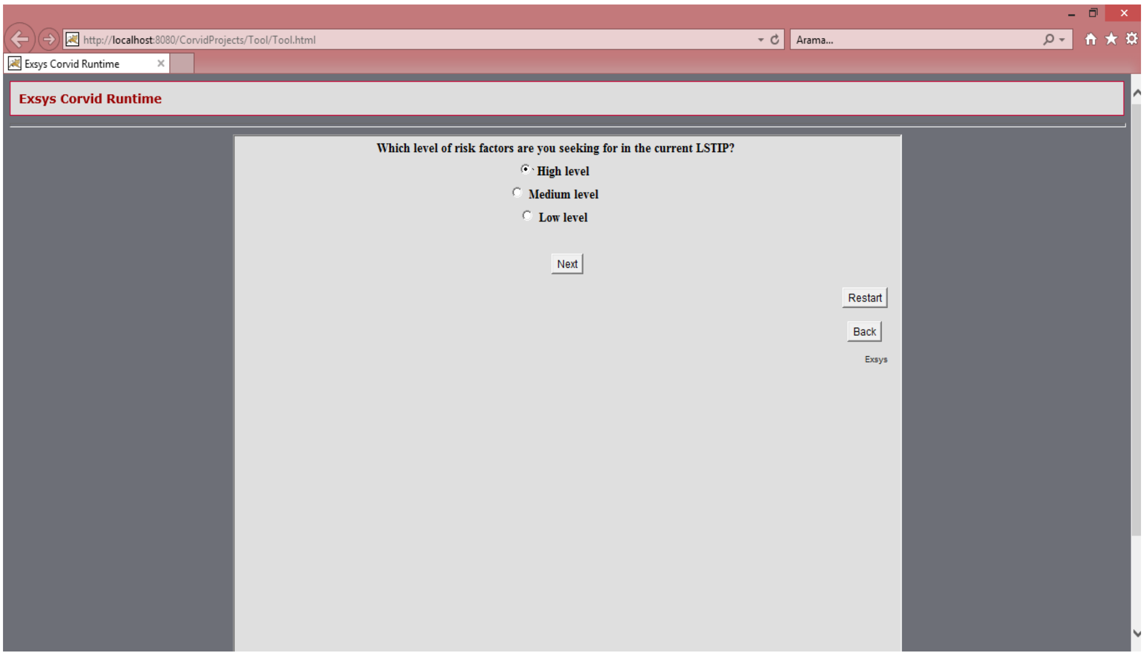

Figure 37: The Function of the Decision Mechanism (The Selection of the Importance Level of the Risk Factors for the Middle East)

In figure 38, based on the current project, the proposed tool asks the user to decide which category of risks he would like to learn. The options range from specific areas (construction to political) to the selection of all at once. In this example, the user has chosen the financial option out of all categories.

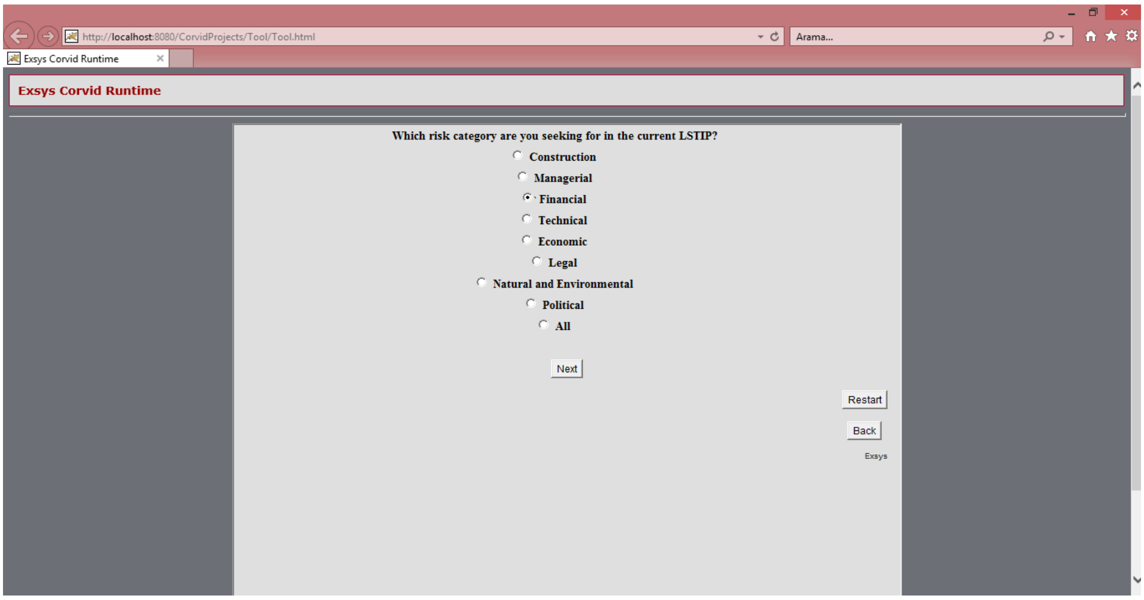

Figure 38: The Function of the Decision Mechanism (The Selection of the Risk Category for the Middle East)

Figure 39 displays all of the selections made by the user in an orderly manner; the region, the type of firm, the role of user, type of the Project, the duration of the project, the level of the risks and all the choices made for the categories. As a result of the selected options in LSTIPs RiDECS tool, the tool has stated the importance level of the financial category according to the Middle East, the importance level of the financial category according to the construction managers in the Middle East, the economic measures that should be taken depending on the project process, the high level risk factors that could occur under the financial category as well as their significance values and the decision to be taken against possible risk factors.

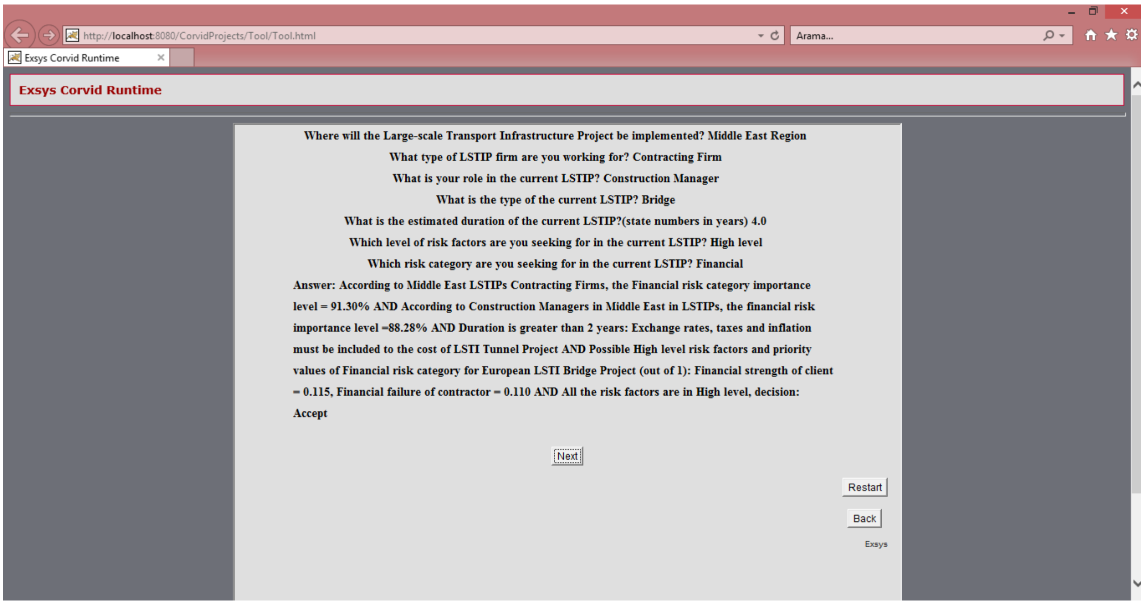

Figure 39: The Results Obtained According to the User's Selections for the Middle East

5.3.4 The Expected Benefits from the Proposed Knowledge-based Tool

The data used in Developed knowledge-based LSTIPs RiDECs tool are collected from project managers, construction managers and civil engineers in companies operating in the LSTIPs in Europe and the Middle East. The companies that were contacted are experienced in the risk area and aim to achieve success policy in the LSTIPs. This increases the use of the tool in LSTIPs in order to identify the risks and to achieve more realistic results with accurate decisions. In addition to this, the LSTIPs developed by the project managers, construction managers and civil engineers working in both regions, with at least ten years of experience, will support the effectiveness, reliability and authenticity of the RiDECS tool. The entire tool used to support decisions in identifying risks or when confronted with risks in LSTIPs is designed to incorporate the features listed below.

5.3.4.1 Rapid Responding

The tool to be designed will be able to respond to questions as fast as an expert and in a reasonable time range. With these characteristics, users will determine risk factors and be informed about the actions taken towards these risks. Thus, the time required for an expert will diminish.

5.3.4.2 High Performance

The proposed expert system is equivalent to at least one expert as it aims to identify the risk factors that could emerge in any type of LSTIP in Europe and the Middle East and the actions that should be taken accordingly. The information obtained from the expert system should meet the expectations of the users.

5.3.4.3 Comprehensibility

The tool will be able to explain the obtained results from beginning to end. The results reached by the tool are clarified within the framework of the rules.

5.3.4.4 Reliability

The tool should be trustworthy for users and make the least possible number of mistakes.

5.4 Risk Management

As today's world is advancing, changing and undergoing a global increase, firms become exposed to ambiguous situations and risks because of alterations in politics, technology and economy. These factors influence the course of the decision making process. Therefore, firms should become familiar with the risk management system to enable the selection of future-directed strategies and the achievement of aims and goals. Sustainability and leadership in a competitive setting demand high risk. Thus, rather than abstaining from risks, they should be managed. Risk management has gained significance in the successful accomplishment of project management. It does not mean taking risks alone but also managing them throughout the way. Clearly, it is based on assessing the ambiguity, analysis, affects and identification of an individual, project or firm in the duration of reaching their aims.

The first stage in the process of managing risks is risk identification. The risk identification stage involves defining the project's risk sources and ambiguous situations as well as clarifying ambiguity and risk responsibilities (Zayed et al., 2008).

5.4.1 Project Risk Management

More complex and large-scale projects have become a current issue in the implementations of the construction sector. Competition increasing among firms entails evaluation not only in terms of performance in these complicated projects but also in terms of time and cost. Providing services in a shorter period of time and at a more reasonable cost than competing firms is an important factor for enterprises (Kutlu, 2001).

Construction projects have many risks and uncertainties. They not only prevent the completion of the projects within the budget and time frame, but they also threaten the quality, security and operational needs (Oztas and Okmen, 2005).

Risk management is the process of ensuring that the project objectives cover risk identification at each stage, risk analysis, risk response plan, control and action planning tasks. Risk management is the sources of uncertainty to estimate the causes of uncertain events and conditions, to estimate and arrange solution strategies in the light of the outputs. Major ambiguities arise in the early stages of the project. Therefore it's essential to determine and assess all risks at the beginning of the project. Risk management is a continuous activity that should proceed during the project (Amos and Dentt, 1997).

One of the key philosophies behind project risk management is the implementation of information generated from the project. This is done by using a risk recording scheme, which means recording and documenting information that emerges during the use of project risk management. Risk recording is a highly effective method that allows the involvement of everyone in the project in order to measure and manage risks consciously within the decision-making process. It also provides a suitable environment for taking risk mitigation measures and making decisions for the future. Risk recording also fosters risk mitigation and action plans in the project. Keeping record of this data will not only provide information for that project, but will also provide background information for future projects.

5.4.1.1 Attitudes Towards Risk

How to cope with risks depends on the project manager's risk tolerance. Four different ways to handle risks when they are identified or confronted are as follows;

Elimination of Risks: The best decision against a risk is to remove it completely. If it is prevented from the initial phase, then it will not cause any harm to the project.

Mitigation of the effects of risks: If it is not possible to prevent a risk, the risk effects could be reduced. Mitigating the risk effects means taking precautions to minimize the risk effects of the projects.

Risk Transfer: Another effective way to deal with risks is to compromise with others who could undertake the risks. Ensuring insurance is one way to do this.

Acceptance of risks: The risk is accepted as a last resort if it is impossible to eliminate, reduce or transfer it. When the risk is accepted, it means that all alternatives have been evaluated and results have been considered.

5.4.2 Planning Phase

Today, it is not possible to envisage an environment where resources, employees and budgets can be used without limit. It is clear that there is a need for a management approach and a programming technique to ensure the most rational use of resources in these conditions, where scarce resources become invaluable in time. It is important to plan and program the process from the beginning to the end of a project in order to evaluate the time and money in the best way and to ensure that resources such as limited materials, labour, machinery and equipment are used in the most appropriate way. Obviously, the planning and programming processes form the basis of project management (Baykan, 2007).

Planning is a way of determining the paths to reach the goal and deciding what to do with them. Organization is an indispensable element of management outweighing its functions such as management, coordination and supervision (Ugur, 2007). It is meaningless to prepare a plan after risks begin emerging in a project. As mentioned, counter plans should be created in the initial phase of a project by identifying risks and adjusting plans accordingly.

A risk management plan is the most useful guide to identify and analyse risks in a project. It shows how risks in the project will be addressed. This type of planning focuses on how the risks will be assessed in line with the plan, those undertaking responsibilities and the frequency carrying out of risk planning. Team meetings should be held in every stage of the project.

To manage risks more effectively and accurately in a risk management plan, the following steps should be taken:

- Categories required to classify risks should be specified. Generally, the most common risks identified are technical risks which are difficult to deal with. Other risks arise from external factors such as changes in the market, risks arising from the weather, etc.
- A risk breakdown structure should be formed. This system is the most ideal tool for managing risk categories. This structure is similar to the work breakdown structure.
- The impact values of the risks should be calculated. If the procedures of risk assessment are implemented accurately, the outcomes will be more evident. The impact value indicates how much harm the risks could give to the project.

Risk management starts with planning. The most effective way to deal with risk management is to address planning at the beginning of the project. Planning provides a robust connection between the design and the production phase. Making accurate and applicable decisions in terms of project objectives is possible by planning the projects in advance. Decisions are held during planning to determine what needs to be done to achieve the project objectives, to specify the workflow accordingly, and to define the relationships between the activities. Throughout project planning, the project manager should assess the risk factors such as safety, cost, quality and time related to the project (Ugur, 2007). Material procurement and contracting strategies should also be followed during the planning phase.

5.4.2.1 Risk Identification

The most important way to determine risks is to collect information from team members. For this reason, the primary method in determining risks is via information collection methods. These are the most effective ways to gather information from team members, stakeholders, or anyone who can provide information about risks. There are many different ways to determine the risks in a project, but brainstorming, interviewing and standard risk lists are the most commonly preferred methods.

5.4.2.2 Risk Assessment

The technology used in the project, the environment in which the project is applied, the relationships among team members, the organization and the cultural competitiveness of the project can affect the flow of the project. Risk Assessment is the rigorous analysis of any cause of harm.

During the process of risk identification, the risk importance level is estimated at first, the possibility of risk occurrence is assessed and finally, the decision on how to manage the risk is made. The level of a risk is determined by analysing the likelihood of its occurrence and the connected effect of the outcome.

To understand whether or not risks are being properly assessed, it is important to examine the most probable way risks could occur and the amount of impact it could have. This process helps determine the likelihood of a risk emergence and to calculate its actual costs. These values are useful in calculating which risks require a significant risk reduction plan. Sometimes the possibility of several risks arising as well as their effects is very low. In such cases, the risk is not addressed. Risks that are not recorded are kept under observation. Risks on the observation list should not be forgotten, but since they do not cause any threats, they do not require prior consideration. However, the observation list should be reviewed occasionally.

5.5 Conceptual Framework 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. Therefore, the risk factors were determined via comprehensive literature review and the relative importance indexes were obtained by means of a questionnaire and ranked according to their importance level.

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. To further support the outcomes, the results of the relative importance index of risk factors obtained were synthesized with the use of NGT and CNM methods to create a proper risk breakdown structure. Accordingly, using the SuperDecision software, the ANP model, which is the same for both regions, was developed and the priority orders of the risk factors were found.

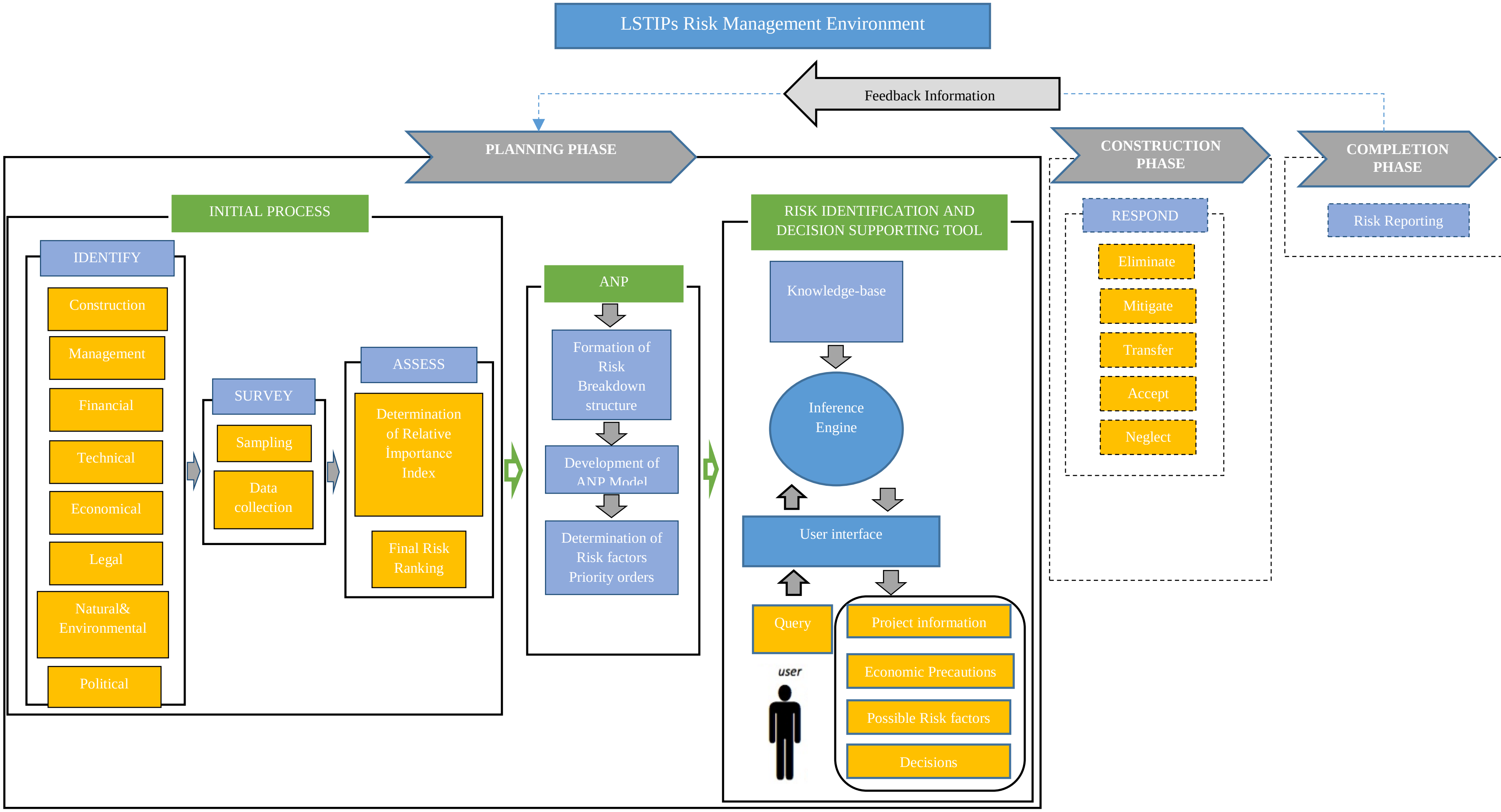

Figure 40: Conceptual Framework of LSTIPs for Planning Phase

LSTIPs' risks can be described as an ambiguous event that leads to failing to accomplish at least one project objective (Cui et al., 2018). The risk management process can raise project performance by controlling the results of risky events on project objectives (Daniel and Daniel, 2018). It is accepted that it is possible to manage risks but not get rid of them. Furthermore, risk assessment is a significant help in decision science for controlling the uncertain events. Failure to make a proper assessment of risks and their effect on project objectives such as project duration and cost can block LSTIPs' success (Nguyen et al., 2018). The objective in risk assessment and analysis is to define the risk position as completely as possible and to prioritize them.

Risk assessment is a systematic, proof-based approach for assessing ambiguous or risky expected events. Here, uncertainty implies to a state where a definite numerical value cannot be given for an activity as some alteration in values may appear due to unpredictable circumstances, while a risk event is described as the probability that an event will arise and considers the impact on corresponding objectives when the event occurs (Farooq et al., 2018). All activities of a LSTIP includes risks and there is an immediate and direct relationship of objectives between the whole project and risk assessment. A set of techniques has been created to assess risks. The approaches, according to Devi (2018), can be divided into qualitative and quantitative analysis. The previous is a process that consists of interviews, checklists and brainstorming while the next is performed through a data driven methodology (Ning et al., 2018). Risk assessment through quantitative analysis describes the effect of each risk in the spectrum of high and low and the probability of occurrence. Although qualitative risk assessment often includes the evaluation of impact and the development of lists in order to further analysis of the highlighted risks (Wu et al., 2018). Qualitative techniques can be lists of risks, risk rankings, or risk maps. These techniques prioritize risks for the next further analysis or action by assessing and combing their probability of occurrence and impact. The risk is assessed in more conceptual terms, such as high, medium or low, depending on the collected opinions and risk tolerance boundaries in the organization. The main qualitative analysis techniques are Brainstorming, cause and effect diagram, checklists, Delphi, Event Tree Analysis and Risk Breakdown Matrix (Pham et al., 2018).

With quantitative analysis techniques, the assessment of risk exposure is related to the application of numerical measures. Here, the impact of results is defined as a financial value and the likelihood by the frequency of risk occurrence based on past series of available data. In brief, quantitative techniques numerically analyze the effect of identified risks on the project objectives (Elzomor et al., 2018). The main quantitative techniques are: Decision tree analysis, expected monetary value, expert judgment, Fault Tree Analysis, fuzzy logic and probability distributions.

Risk assessment starts with planning that is most effective way to deal with risk management is to address planning at the beginning of a LSTIP (Mao et al., 2018). Throughout project planning, the project manager assess the risk factors such as safety, cost, quality and time related to LSTIP. During the process of the risk importance level is estimated at first, the possibility of risk occurrence is assessed and finally, the decision on how to manage the risk is made.

Risk responses ensure the successful accomplishment of the project. Therefore, in order to make further advancements in the study, a tool with a knowledge-base that includes information about projects, risk factors and their priority order lists as well as a inference engine that includes rules and criteria at the same time, and an user interface that the user can easily understand has been developed.

Figure 40 clearly demonstrates the conceptual framework 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.

Chapter 6

CONCLUSIONS

6.1 Theoretical Contributions

This thesis presents a process for identifying and assessing risk factors under categories which could emerge in European and Middle Eastern LSTIPs. An extensive literature review was initially conducted to determine the risks and factors that could occur in LSTIPs in both areas. 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.

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.

Afterwards, the significances determined for fifty risk factors were synthesized to obtain forty risk factors by means of NGT and CNM. To provide efficiency and prevent misunderstandings, a risk breakdown structure consisting of five risk factors listed under eight different categories was created.

Identified risk factors that could be confronted in LSTIPs in Europe and the Middle East were used to develop an ANP model. With the application of Super Decisions software, the order of priority for the risk factors was created separately for both regions. Additionally, the orders of priority for Europe and the Middle East were compared to test their consistency via two different case studies. Correspondingly, informative meetings with qualified experts were conducted, and a hierarchical risk breakdown structure was formed.

With the hierarchical risk breakdown structure, Super Decisions software was used to constitute an ANP model. The pairwise comparisons obtained from the ANP model were completed in collaboration with experts qualified in European and Middle Eastern LSTIPs. These pairwise comparison matrix values were used in the Super Decisions software to achieve the limit super matrix, i.e., to determine the orders of priority for risks.

The results of this study used to compare the orders of priority and risk factors of Europe and the Middle East are as follows:

- The insufficient economic situation of the project owners was identified as the most likely and crucial risk in the financial category for both Europe and the Middle East.
- The change in the scope of work, inappropriate contracting and poor definition of scope display an equal and prior importance for encountering risks in the construction, technical and legal areas of European and Middle Eastern countries.
- In the natural and environmental risk category, flood is considered as the greatest threat for Europe, whereas for the Middle East, water pollution is identified as the largest risk.
- While Europe is primarily concerned with the contractor's poor management ability risk factor in the management category, the Middle East places emphasis on the loss of control.
- The most significant risk factor in the economic category was defined as resource availability and as increased material cost for Europe and the Middle East, respectively.

- In the political category, rigid bureaucracy was determined as the prime risk factor for Europe, whereas unsupportive government policies were found to be the prime risk factor for the Middle East.

To further support the results in this study, two LSTIPs, one in Europe and the other the Middle East, were selected to consider two case studies. In the railway project case study, although problems were encountered in some categories, none were confronted in the other categories. In fact, it was clearly observable that the priority order of risks and factors appearing in a project implemented in Europe corresponds to the priority order of the risks obtained from the ANP model. Similarly, the case study for the Middle East tunnel project highlighted that risks were faced in a certain number of categories. Furthermore, the priority order and risks concurred with those acquired from the ANP model. Therefore, it was evident that the results of the developed ANP model implemented in this study are consistent with the results of the case studies. In conclusion, this research study highlighted the risks possibly occurring in LSTIPs in Europe and the Middle East and contributes to the identification and assessment process in the planning phase.

In addition, by using the developed ANP model and its results, a questionnaire was conducted to firms operating in European and Middle Eastern LSTIPs in order to test whether or not this method will be useful and applicable for future LSTIPs. The improvement degree results from the test and the significance orders of risk factors obtained from the ANP model are complementary.

In this study, several examples have been given on how the compilation of risk factors that possibly emerges according to the types of LSTIPs in Europe and the

Middle East, the roles in the project, the durations of projects are converted to a computer aided knowledge-based LSTIPs RiDECS tool. This study could be carried out in a longer time frame within the scope of multi-members involved in the project. At the same time, the developed LSTIPs RiDECS tool presents the applicability of the expert system. Lastly, it also provides a conceptual framework which covers whole study that guides firms in identifiying and giving decisions against risks in the planning phase.

6.2 Managerial Implications

This study has produced outcomes that could enlighten managers working in the area of LSTIPs and has also provided a beneficial guide for risk assessment. Depending on the type of project, the identification of risks in the planning process affects the faith as well as the success of the project. Figure 8, demonstrating the risk categories and factors that could occur in LSTIPs, is a clear example of this finding. In the process of decision making, by applying one of the MCDM methods, managers are assisted in assessing risks and in using business resources more efficiently. This study consists of a MCDM method that assesses numerous strategic and operational factors concurrently. In the assessment of risks, an ANP model that includes inner dependency, outer dependency and feedback qualities as well as presents explicit results is implemented. With the classification of project risk categories and factors during the planning stage, the ANP method is used as a tool to evaluate and ensure the success of the project and to mitigate problems.

Managers could develop an ANP model in the company they work for. Figure 9 demonstrates an example of a risk assessment model in LSTIPs. Here, the ANP model reflects the interdependencies of risk categories, factors and main criteria in detail. Pairwise comparisons consist of consistency indices and limit super matrices obtained by a software program. Pairwise comparisons enabled the ranking of the priorities among factors. Consistency indices test the validity of these comparisons. The limit super matrix reveals the priority values of the risk factors; moreover, it explicitly manifests the comparisons of risk factors' priority orders confronted in different regions along with the inadequacies and common grounds in these regions. This ANP model may draw attention to many stakeholders as well as be a focus point for companies. The results obtained from this study could serve as a guideline and contribute to prospective projects. Furthermore, the results could be used to compare and contrast the priority orders of risks in future analytic studies and determine variations. This ANP model achieves positive outcomes by minimizing the number of risks and advancing at a well-grounded pace. The knowledge-based LSTIPs RiDECS tool proposed in this study will be a guide for European and Middle Eastern firms, their project managers, construction managers and civil engineers operating LSTIPs in identifying risks and supporting decisions more efficiently and rapidly in the planning phase.

The results indicated that the differences between European and Middle Eastern risk priority orders are introduced by factors that include the geographical location, laws and economies of the regions as well as the diverse ethnicities of the managers. In addition, the risk factors and priority orders could gain importance in the international arena and pave the way for projects in other regions. Moreover, the results of this study encourage managers and companies to develop an understanding of risk assessment benefits and gives rise to more successful projects in the future.

6.3 Research Limitations

While this study proposed a range of opportunities for future research, it also has limitations. Because the type and number of risks encountered in other project types may vary, the risk factors and categories identified for analysis in this study were firstly specified to LSTIP type. The regions where many LSTIPs built today and are still under construction are located in Europe and the Middle East therefore; secondly, this research was conducted in only two regions of the world: Europe and the Middle East. Thirdly, this research consisted of project managers and construction managers working in contracting firms as well as civil engineers working in engineering consulting firms that operate in Europe and the Middle East, meaning this study was limited to three different roles. Lastly, this project focused on the risks confronted during the planning and construction phases and thus is limited to supporting prospective projects only in the planning stage. Future studies should involve alternative European and Middle Eastern countries and firms to further promote the validity of the findings obtained in this study.

6.4 Avenues for Future Research

By taking into account the risk factors determined from the literature review, priority orders of the risk factors obtained by the ANP model as well as the LSTIPs risk identification and decision supporting tool developed with knowledge-base, the following recommendations are put forward for LSTIPs' construction firms operating in Europe and the Middle East as well as project managers, construction managers and civil engineers that take part in LSTIPs in both regions and future studies:

1) The reactions of firms, project managers, construction managers and civil engineers towards the risks confronted in LSTIPs in Europe and the Middle East could be investigated.
2) Analysing the results of the actions taken by firms, project manager, construction manager and civil engineer, and their recommendations to mitigate or eliminate these risks could be an area of focus.
3) The ANP model developed in this study can be adapted based on a specific type of LSTIP to further refine the possible risk factors that could occur.
4) With the risk factors obtained, a comparison can be made with the data in this study by using a different multi-attribute decision making method.
5) The LSTIPs risk identification and decision supporting tool developed in this study could be further improved by converting it to a facilitative tool that focuses on how the risks in the construction phases could be discarded and reduced.
6) The results of the ANP model can be compared and updated by eliciting opinions of other stakeholders experienced in LSTIPs in Europe or the Middle East who are not included in this study.
7) Based on a specific country developed in LSTIPs in Europe or the Middle East, the ANP model can be applied and the results can be juxtaposed with the data in this study.

To conclude, because research has been conducted and developed in the area of LSTIPs in the same regions and in the application of different multi-attribute decision making methods, the work undertaken in this thesis will be verified and updated. Furthermore, the process followed in this thesis will be an example to LSTIPs operated in other regions. Finally, the LSTIPs RiDECS tool developed and presented in this thesis can be further developed by upgrading the tool with a broader range of stakeholders and more various types of firms that will mitigate the risks and increase the success of LSTIPs.

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APPENDICES

Appendix A: Firms Questionnaire Form

Evaluation of the Relative Importance of Risk Factors and Categories in Large-scale Transport Infrastructure Projects

1. Email address

____

Dear Sir/Madam, you are kindly invited to voluntarily participate to a survey which has been prepared based on risk categories and their factors in Large-scale Transport Infrastructure projects. This survey is a part of the risk assessment process of a PhD study conducted by Fikri Yücelgazi under the supervision of Assoc. Prof. Dr. İbrahim Yitmen in the Department of Civil Engineering at Eastern Mediterranean University in North Cyprus. The target of this survey is to rank risk categories and factors regarding the importance level in Large-scale Transport infrastructure projects based on your background knowledge and experience. The results of this survey will be used in analyzing the relative importance of risk factors under each category. The survey will take 5 - 10 minutes to complete and your responses will be kept confidential. If you have any questions about this survey, feel free to contact Fikri Yücelgazi via fikri.yucelgazi1@gmail.com .Your participation and feedback is highly appreciated. Thank you for your time and cooperation.

The first part of this survey aims to collect personal information about the participants

1. In which country/countries have you taken part in the implementation of large-scale

Transport infrastructure project(s)? (You can select one option)

☐ Europe

☐ Middle East

2. What is/was the type of the firm you are currently working for?

(Select only one option)

☐ Contracting Firm

☐ Engineering Consulting Firm

3. What was / is your role in the large-scale transport infrastructure project(s)?

(Select only one option)

☐ Project Manager

☐ Construction Manager

☐ Civil Engineer

4. How many years of experience do you have in large-scale transport infrastructure

Projects? *(Select only one option)*

☐ <5 years

☐ 5-10 years

☐ 11-20 years

☐ >20 years

5. What type(s) of large-scale transport infrastructure project(s) have you taken part in? (You can select more than one option)

☐ Tunnel

☐ Bridge

☐ Highway

☐ Railway

☐ Metro Rail (Subway)

6. What is the largest size of project you have taken part in so far and in which project type? (Select only one option in the experienced area)

	Less than 50 km	Between 50-100 Km	Between 100-150 Km	More than 200 km
Tunnel				
Bridge				
Highway				
Railway				
Metro Rail (subway)				

7. What is the total cost of all the projects you have taken part in so far (in dollars)? *

(Select only one option)

☐ Less than 1 billion

☐ Between 1-5 billion

☐ Between 6-10 billion

☐ More than 10 billion

8. What is/are the risk factor/s you mostly encountered under the Construction category in the last completed LSTIP you worked for? *(Fill only one project type column. You can select more than one factor)*

Risk factor	Project type				
	Tunnel	Bridge	Highway	Railway	Subway
Change in scope of work					
Lack of experienced workers					
Poor coordination among the consultants					
Faulty construction techniques					
Cost escalation					
Inadequate construction planning					
Low safety awareness					

9. What is/are the risk factor/s you mostly encountered under the Management category in the last completed LSTIP you worked for? *(Fill only one project type column. You can select more than one factor)*

Risk factor	Project type				
	Tunnel	Bridge	Highway	Railway	Subway
Labour disputes and strikes					
Loss of control					
Improper project feasibility and planning					
Unrealistic scheduling					
Poor communications among stakeholders					
Contractors' poor management ability					

10. What is/are the risk factor/s you mostly encountered under the Financial category in the last completed LSTIP you worked for? *(Fill only one project type column. You can select more than one factor)*

Risk factor	Project type				
	Tunnel	Bridge	Highway	Railway	Subway
Rentals					
Financial strength of client					
Financial failure of contractor					
Design variations					
Incomplete or inaccurate cost estimate					
Inadequate site information					

11. What is/are the risk factor/s you mostly encountered under the Technical category in the last completed LSTIP you worked for? *(Fill only one project type column. You can select more than one factor)*

Risk factor	Project type				
	Tunnel	Bridge	Highway	Railway	Subway
Changes to the technology used					
Insufficient or incorrect design information					
Shortage of skills or techniques					
Poor definition of scope					
Material suitability and accessibility and shortage					
Inadequate time allocation					
Employment of inexperienced designers					

12. What is/are the risk factor/s you mostly encountered under the Economic category in the last completed LSTIP you worked for? *(Fill only one project type column. You can select more than one factor)*

Risk Factor	Project type				
	Tunnel	Bridge	Highway	Railway	Subway
Inflation					
Exchange rates fluctuation					
Increased materials cost					
Economic crisis					
Tax rate					
Resources availability					

13. What is/are the risk factor/s you mostly encountered under the legal category in the last completed LSTIP you worked for? *(Fill only one project type column. You can select more than one factor)*

Risk factor	Project type				
	Tunnel	Bridge	Highway	Railway	Subway
Breach of agreements					
Conflict in laws					
Inappropriate contracting					
Misinterpretation					
Nationalism and local protectionism					

14. What is/are the risk factor/s you mostly encountered under the Natural&environmental category in the last completed LSTIP you worked for? *(Fill only one project type column. You can select more than one factor)*

Risk factor	Project type				
	Tunnel	Bridge	Highway	Railway	Subway
Earthquake					
Flood					
Unforeseen adverse site conditions					
Water pollution					
Wind (storm)					

15. What is/are the risk factor/s you mostly encountered under the political category in the last completed LSTIP you worked for? *(Fill only one project type column. You can select more than one factor)*

Risk factor	Project type				
	Tunnel	Bridge	Highway	Railway	Subway
Bribery					
Changes of planning					
Rigid bureaucracy					
Unsupportive government policies					
War and civil disorder					

16. Did the last LSTIP firm you worked for get a loan from the bank? *(Select only one option)*

☐ Yes

☐ No

17. What was the duration of the last LSTIP you worked for? *(Select only one option)*

☐ 2 < years

☐ 2 > years

This is the end of the first section

The second part of this survey aims to order the relative importance of each risk category as well as the risk factors under these risk categories in Large-scale transport infrastructure projects.

18. Please mark the importance level of each large-scale transport infrastructure project risk category given below * *(Mark only one option per row)*

	Unimportant	Somewhat important	Quite important	Strongly important	Extremely important
Construction risks					
Management risks					
Financial risks					
Technical risks					
Economic risks					
Legal risks					
Natural& Environmental Risks					
Political risks					

19. Please mark the importance level for each "construction" related risk factor in large-scale transport infrastructure projects * *(Mark only one option per row)*

	Unimportant	Somewhat important	Quite important	Strongly important	Extremely important
Change in scope of work					
Lack of experienced workers					
Poor coordination among the consultants					
Faulty construction techniques					
Cost escalation					
Inadequate construction planning					
Low safety awareness					

20. Please mark the importance level for each "management" related risk factor in large-scale transport infrastructure projects * *(Mark only one option per row)*

	Unimportant	Somewhat important	Quite important	Strongly important	Extremely important
Labour disputes and strikes					
Loss of control					
Improper project feasibility and planning					
Unrealistic scheduling					
Poor communications among stakeholders					
Contractors' poor management ability					

21. Please mark the importance level for each "financial" related risk factor in large-scale transport infrastructure projects * *(Mark only one option per row)*

	Unimportant	Somewhat important	Quite important	Strongly important	Extremely important
Rentals					
Financial strength of client					
Financial failure of contractor					
Design variations					
Incomplete or inaccurate cost estimate					
Inadequate site information					

22. Please mark the importance level for each "technical" related risk factor in large-scale transport infrastructure projects * *(Mark only one option per row)*

	Unimportant	Somewhat important	Quite important	Strongly important	Extremely important
Employment of inexperienced designers					
Changes to the technology used					
Insufficient or incorrect design information					
Shortage of skills or techniques					
Poor definition of scope					
Material suitability and accessibility and shortage					
Inadequate time allocation					
Employment of inexperienced designers					
Changes to the technology used					

23. Please mark the importance level for each "economy" related risk factor in large-scale transport infrastructure projects * *(Mark only one option per row)*

	Unimportant	Somewhat important	Quite important	Strongly important	Extremely important
Inflation					
Exchange rates fluctuation					
Increased materials cost					
Economic crisis					
Tax rate					
Resources availability					

24. Please mark the importance level for each "legal" related risk factor in large-scale transport infrastructure projects * *(Mark only one option per row)*

	Unimportant	Somewhat important	Quite important	Strongly important	Extremely important
Permits and licenses					
Conflict in laws					
Breach of agreements					
Misinterpretation					
Inappropriate contracting					
Nationalism and local protectionism					

25. Please mark the importance level for each "natural and environmental" related risk factor in large-scale transport infrastructure projects **(Mark only one option per row)*

	Unimportant	Somewhat important	Quite important	Strongly important	Extremely important
Fire					
Water pollution					
Flood					
Earthquake					
Wind (storm)					
Unforeseen adverse site conditions					

26. Please mark the importance level for each "political" related risk factor in large-scale transport infrastructure projects **(Mark only one option per row)*

	Unimportant	Somewhat important	Quite important	Strongly important	Extremely important
Changes of planning					
Unsupportive government policies					
Rigid bureaucracy					
Embargoes					
War and civil disorder					
Bribery					

Appendix B: Pairwise Comparison Questionnaire Form

Pairwise Comparison of Risk Categories and Factors in Large-scale Infrastructure Projects

Dear Sir/Madam, you are kindly invited to voluntarily participate to a survey which has been prepared based on risk categories and their factors in Large-scale Transport Infrastructure projects. This survey is a part of the risk assessment process of a PhD study conducted by Fikri Yücelgazi under the supervision of Assoc. Prof. Dr. İbrahim Yitmen in the Department of Civil Engineering at Eastern Mediterranean University in North Cyprus. The target of this survey is to compare the importance level of the risk factors under eight categories in Large-scale Transport infrastructure projects based on your background knowledge and experience. The results of this survey will be used in Analytical Network Process (ANP) to find out the priorities of risk factors. The survey will take 5 - 10 minutes to complete and your responses will be kept confidential. If you have any questions about this survey, feel free to contact Fikri Yücelgazi via fikri.yucelgazi1@gmail.com .Your participation and feedback is highly appreciated. Thank you for your time and cooperation.

There are eight categories and forty risk factors in this questionnaire; each table represents the factors under different categories. The tables will be filled with numbers by using saaty scale given below;

Saaty Scale

Intensity of importance	Definition
9	Extremely important
7	Very strongly important
5	Strongly important
3	Moderately important
1	Equally important
1/3	Moderately not important
1/5	Not important
1/7	Less important
1/9	Minimally important
2,4,6,8 and 1/2,1/4,1/6,1/8	Intermediate values

For example, considering the construction cluster presented in sample table, when the factor of faulty construction techniques is compared to the factor of inadequate construction planning, the value is 5, indicating that the factor of faulty construction techniques is strongly more important than the factor of the inadequacy of construction planning. On the other hand, when the cost escalation is compared to the factor of faulty construction techniques, the value is 1/5, indicating that the factor of cost escalation is not important than factor of faulty construction techniques.

Sample of Pairwise comparison;

Construction Cluster

	Change in scope of work	Cost escalation	Faulty construction techniques	Inadequate construction planning	Poor coordination among the consultants
Change in scope of work	1	4	1	4	2
Cost escalation		1	1/5	3	3
Faulty construction techniques			1	5	2
Inadequate construction planning				1	½
Poor coordination among the consultants					1

1. Please compare the importance level between each pair of risk categories in large-scale transport infrastructure projects (Use Saaty scale numbers and only fill highlighted spaces)

	Construction	Management	Financial	Technical	Economic	Legal	Natural&Environmental	Political
Construction	1							
Management		1						
Financial			1					
Technical				1				
Economic					1			
Legal						1		
Natural&Environmental							1	
Political								1

2. Please compare the importance level between each pair of risk factors under "Construction" category in large-scale transport infrastructure projects (Use Saaty scale numbers and only fill highlighted spaces)

	Change in scope of work	Cost escalation	Faulty construction techniques	Inadequate construction planning	Poor coordination among the consultants
Change in scope of work	1				
Cost escalation		1			
Faulty construction techniques			1		
Inadequate construction planning				1	
Poor coordination among the consultants					1

3. Please compare the importance level between each pair of risk factors under "Management" category in large-scale transport infrastructure projects (Use Saaty scale numbers and only fill highlighted spaces)

	Contractors' poor management ability	Improper project feasibility and planning	Loss of control	Poor communications among stakeholders	Unrealistic scheduling
Contractors' poor management ability	1				
Improper project feasibility and planning		1			
Loss of control			1		
Poor communications among stakeholders				1	
Unrealistic scheduling					1

4. Please compare the importance level between each pair of risk factors under "Financial" category in large-scale transport infrastructure projects (Use Saaty scale numbers and only fill highlighted spaces)

	Design variations	Financial failure of contractor	Financial strength of client	Inadequate site information	Incomplete or inaccurate cost estimate
Design variations	1				
Financial failure of contractor		1			
Financial strength of client			1		
Inadequate site information				1	
Incomplete or inaccurate cost estimate					1

5. Please compare the importance level between each pair of risk factors under “Technical” category in large-scale transport infrastructure projects (Use Saaty scale numbers and only fill highlighted spaces)

	Employment of inexperienced designers	Insufficient or incorrect design information	Poor definition of scope	Material suitability and accessibility and shortage	Inadequate time allocation
Employment of inexperienced designers	1				
Insufficient or incorrect design information		1			
Poor definition of scope			1		
Material suitability and accessibility and shortage				1	
Inadequate time allocation					1

6. Please compare the importance level between each pair of risk factors under “Economic” category in large-scale transport infrastructure projects (Use Saaty scale numbers and only fill highlighted spaces)

	Inflation	Exchange rates fluctuation	Increased materials cost	Economic crisis	Resources availability
Inflation	1				
Exchange rates fluctuation		1			
Increased materials cost			1		
Economic crisis				1	
Resources availability					1

7. Please compare the importance level between each pair of risk factors under "Legal" category in large-scale transport infrastructure projects (Use Saaty scale numbers and only fill highlighted spaces)

	Conflict in laws	Breach of agreements	Misinterpretation	Inappropriate contracting	Nationalism and local protectionism
Conflict in laws	1				
Breach of agreements		1			
Misinterpretation			1		
Inappropriate contracting				1	
Nationalism and local protectionism					1

8. Please compare the importance level between each pair of risk factors under "Natural&Environmental" category in large-scale transport infrastructure projects (Use Saaty scale numbers and only fill highlighted spaces)

	Water pollution	Flood	Earthquake	Wind (storm)	Unforeseen adverse site conditions
Water pollution	1				
Flood		1			
Earthquake			1		
Wind (storm)				1	
Unforeseen adverse site conditions					1

9. Please compare the importance level between each pair of risk factors under “Political” category in large-scale transport infrastructure projects (Use Saaty scale numbers and only fill highlighted spaces)

	Changes of planning	Unsupportive government policies	Rigid bureaucracy	War and civil disorder	Bribery
Changes of planning	1				
Unsupportive government policies		1			
Rigid bureaucracy			1		
War and civil disorder				1	
Bribery					1

Appendix C: The tables of the Limit Super Matrix for Europe and the Middle East

Table Limit Super matrix for the Middle East Region

		1 construction risks					2 management risks				
		Change in scope of work	Cost escalation	Faulty construction techniques	Inadequate construction planning	Poor coordination among the consultants	Contractors' poor management ability	improper project feasibility and planning	Loss of control	Poor communications among stakeholders	Unrealistic scheduling
1 Construction Risks	Change in scope of work	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
	Cost escalation	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
	Faulty construction techniques	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
	Inadequate construction planning	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054
	Poor coordination among the consultants	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981
2 management risks	Contractors' poor management ability	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442
	improper project feasibility and planning	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961
	Loss of control	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836
	Poor communications among stakeholders	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848
	Unrealistic scheduling	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127
3 financial risks	Design variations	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690
	Financial failure of contractor	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993
	Financial strength of client	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415
	Inadequate site information	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419
	Incomplete or inaccurate cost estimate	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691
4 technical risks	Employment of inexperienced designers	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539
	Inadequate time allocation	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230
	Insufficient or incorrect design information	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230
	Material suitability and accessibility and shortage	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539
	Poor definition of scope	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300
5 economic risks	Economic crisis	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862
	Exchange rates fluctuation	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681
	Increased materials cost	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119
	Inflation	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888
	Resources availability	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054
6 legal risks	Breach of agreements	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342
	Conflict in laws	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638
	Inappropriate contracting	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875
	Misinterpretation	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638
	Nationalism and local protectionism	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154
7 natural&environmental risks	Earthquake	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513
	Flood	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513
	Unforeseen adverse site conditions	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926
	Water pollution	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469
	Wind (storm)	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513
8 political risks	Bribery	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062
	Changes of planning	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770
	Rigid bureaucracy	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461
	Unsupportive government policies	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165
	War and civil disorder	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995
Control Criteria	Large-scale transport infrastructure project risk	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Table Continuation of Limit Super matrix for the Middle East Region

3 financial risks					4 technical risks				
Design variations	Financial failure of contractor	Financial strength of client	Inadequate site information	Incomplete or inaccurate cost estimate	Employment of inexperienced designers	Inadequate time allocation	Insufficient or incorrect design information	Material suitability and accessibility and shortage	Poor definition of scope
0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054
0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981
0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442
0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961
0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836
0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848
0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127
0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690
0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993
0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415
0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419
0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691
0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539
0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230
0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230
0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539
0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300
0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862
0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681
0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119
0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888
0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054
0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342
0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638
0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875
0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638
0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154
0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513
0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513
0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926
0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469
0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513
0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062
0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770
0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461
0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165
0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Table Continuation of Limit Super matrix for the Middle East Region

5 economic risks					6 legal risks				
Economic crisis	Exchange rates fluctuation	Increased materials cost	Inflation	Resources availability	Breach of agreements	Conflict in laws	Inappropriate contracting	Misinterpretation	Nationalism and local protectionism
0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054
0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981
0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442
0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961
0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836
0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848
0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127
0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690
0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993
0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415
0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419
0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691
0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539
0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230
0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230
0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539
0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300
0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862
0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681
0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119
0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888
0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054
0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342
0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638
0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875
0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638
0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154
0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513
0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513
0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926
0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469
0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513
0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062
0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770
0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461
0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165
0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Table Continuation of Limit Super matrix for the Middle East Region

7 natural&environmental risks					8 political risks					Control Criteria
Earthquake	Flood	Unforeseen adverse site conditions	Water pollution	Wind (storm)	Bribery	Changes of planning	Rigid bureaucracy	Unsupportive government policies	War and civil disorder	Large-scale transport infrastructure project risk
0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054
0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981
0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442
0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961
0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836
0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848
0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127
0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690	0.023690
0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993	0.110993
0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415	0.115415
0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419	0.043419
0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691	0.078691
0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539
0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230
0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230	0.004230
0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539	0.012539
0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300	0.023300
0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862	0.012862
0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681	0.008681
0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119	0.029119
0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888	0.004888
0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054	0.028054
0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342	0.005342
0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638
0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875	0.017875
0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638	0.001638
0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154	0.003154
0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513
0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513
0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926	0.008926
0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469	0.045469
0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513	0.024513
0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062	0.003062
0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770	0.004770
0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461	0.012461
0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165	0.036165
0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995	0.002995
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Table Limit super matrix for Europe Region

		1 construction risks					2 management risks				
		Change in scope of work	Cost escalation	Faulty construction techniques	Inadequate construction planning	Poor coordination among the consultants	Contractors' poor management ability	improper project feasibility and planning	Loss of control	Poor communications among stakeholders	Unrealistic scheduling
1 construction risks	Change in scope of work	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793
	Cost escalation	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300
	Faulty construction techniques	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350
	Inadequate construction planning	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300
	Poor coordination among the consultants	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360
2 management risks	Contractors' poor management ability	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583
	improper project feasibility and planning	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995
	Loss of control	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606
	Poor communications among stakeholders	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995
	Unrealistic scheduling	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034
3 financial risks	Design variations	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907
	Financial failure of contractor	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121
	Financial strength of client	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679
	Inadequate site information	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632
	Incomplete or inaccurate cost estimate	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870
4 technical risks	Employment of inexperienced designers	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340
	Inadequate time allocation	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202
	Insufficient or incorrect design information	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202
	Material suitability and accessibility and shortage	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262
	Poor definition of scope	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833
5 economic risks	Economic crisis	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612
	Exchange rates fluctuation	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612
	Increased materials cost	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630
	Inflation	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120
	Resources availability	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630
6 legal risks	Breach of agreements	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567
	Conflict in laws	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231
	Inappropriate contracting	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387
	Misinterpretation	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231
	Nationalism and local protectionism	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231
7 natural&environmental risks	Earthquake	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194
	Flood	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038
	Unforeseen adverse site conditions	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194
	Water pollution	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376
	Wind (storm)	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131
8 political risks	Bribery	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753
	Changes of planning	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345
	Rigid bureaucracy	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670
	Unsupportive government policies	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456
	War and civil disorder	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228
Control Criteria	Large-scale transport infrastructure project risk	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Table Continuation of Limit super matrix for Europe Region

3 financial risks					4 technical risks				
Design variations	Financial failure of contractor	Financial strength of client	Inadequate site information	Incomplete or inaccurate cost estimate	Employment of inexperienced designers	Inadequate time allocation	Insufficient or incorrect design information	Material suitability and accessibility and shortage	Poor definition of scope
0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793
0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300
0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350
0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300
0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360
0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583
0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995
0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606
0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995
0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034
0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907
0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121
0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679
0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632
0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870
0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340
0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202
0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202
0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262
0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833
0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612
0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612
0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630
0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120
0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630
0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567
0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231
0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387
0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231
0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231
0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194
0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038
0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194
0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376
0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131
0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753
0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345
0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670
0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456
0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Table Continuation of Limit super matrix for Europe Region

5 economic risks					6 legal risks				
Economic crisis	Exchange rates fluctuation	Increased materials cost	Inflation	Resources availability	Breach of agreements	Conflict in laws	Inappropriate contracting	Misinterpretation	Nationalism and local protectionism
0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793
0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300
0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350
0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300
0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360
0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583
0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995
0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606
0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995
0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034
0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907
0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121
0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679
0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632
0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870
0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340
0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202
0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202
0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262
0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833
0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612
0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612
0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630
0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120
0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630
0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567
0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231
0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387
0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231
0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231
0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194
0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038
0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194
0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376
0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131
0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753
0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345
0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670
0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456
0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Table Continuation of Limit super matrix for Europe Region

7 natural&environmental risks					8 political risks					Control Criteria
Earthquake	Flood	Unforeseen adverse site conditions	Water pollution	Wind (storm)	Bribery	Changes of planning	Rigid bureaucracy	Unsupportive government policies	War and civil disorder	Large-scale transport infrastructure project risk
0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793
0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300
0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350
0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300
0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360
0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583
0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995
0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606
0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995
0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034	0.020034
0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907	0.031907
0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121	0.087121
0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679	0.133679
0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632	0.033632
0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870	0.085870
0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340	0.016340
0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202
0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202	0.006202
0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262	0.006262
0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833	0.021833
0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612
0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612	0.010612
0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630
0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120	0.007120
0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630	0.027630
0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567	0.008567
0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231
0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387	0.011387
0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231
0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231	0.003231
0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194
0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038	0.054038
0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194	0.020194
0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376	0.022376
0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131	0.011131
0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753	0.004753
0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345	0.007345
0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670	0.018670
0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456	0.011456
0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228	0.017228
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Appendix D: Screenshot of Limit Super Matrix in Software

A section of the Europe Limit Super Matrix

Super Decisions Main Window: Middle-east Large-scale Transport Infrastructure Project Risk .sdmod: Limit Matrix

Cluster Node Labels		1 construction risks					2 management risks		
		Change in scope of work	Cost escalation	Faulty construction techniques	Inadequate construction planning	Poor coordination among the consultants	Contractors' poor management ability	improper project feasibility and planning	Loss of control
1 construction risks	Change in scope of work	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793	0.054793
	Cost escalation	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300
	Faulty construction techniques	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350	0.015350
	Inadequate construction planning	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300	0.033300
	Poor coordination among the consultants	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360	0.022360
2 management risks	Contractors' poor management ability	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583	0.040583
	improper project feasibility and planning	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995	0.011995
	Loss of control	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606	0.026606

Done

A section of the Middle East Limit Super Matrix

Super Decisions Main Window: Large-scale Transport Infrastructure Project Risk .sdmod: Limit Matrix

Cluster Node Labels		1 construction risks					2 management risks		
		Change in scope of work	Cost escalation	Faulty construction techniques	Inadequate construction planning	Poor coordination among the consultants	Contractors' poor management ability	improper project feasibility and planning	Loss of control
1 construction risks	Faulty construction techniques	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356	0.041356
	Inadequate construction planning	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054	0.013054
	Poor coordination among the consultants	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981	0.021981
2 management risks	Contractors' poor management ability	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442	0.041442
	improper project feasibility and planning	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961	0.009961
	Loss of control	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836	0.042836
	Poor communications among stakeholders	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848	0.009848
	Unrealistic scheduling	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127	0.007127

Done

Appendix E: Evaluation of Analytical Network Process Questionnaire Form for European Region

Evaluation of Proposed Analytical Network Process Model and Results of Analysis for Large-scale Transport Infrastructure Projects

Dear Sir/Madam, you are kindly invited to voluntarily participate to a survey which has been prepared based on the Analytical Network Process **(**ANP) model and the risk priority results for Large-scale Transport Infrastructure Projects. This survey is a part of the risk assessment process of a PhD study conducted by Fikri Yücelgazi under the supervision of Assoc. Prof. Dr. İbrahim Yitmen in the Department of Civil Engineering at Eastern Mediterranean University in North Cyprus. The target of this survey is to find out to what extent the results of the ANP analysis can improve project risks and to determine the applicability of the proposed ANP model in Large-scale Transport infrastructure projects based on the results of analysis and the ANP model given below for European region. The survey will take 5 - 10 minutes to complete and your responses will be kept confidential. If you have any questions about this survey, feel free to contact Fikri Yücelgazi via fikri.yucelgazi1@gmail.com .Your participation and feedback is highly appreciated. Thank you for your time and cooperation.

Analytical Network Process

An ANP - an effective and realistic solution for complex decision making problems - was introduced in 1996 by Thomas L. Saaty. ANP is defined as a MCDM that takes the qualitative values as well as the quantitative values into consideration and models the problem in a hierarchical structure and takes into account the relationships and interactions between the modelling criteria.

There are eight categories and forty risk factors in this model.

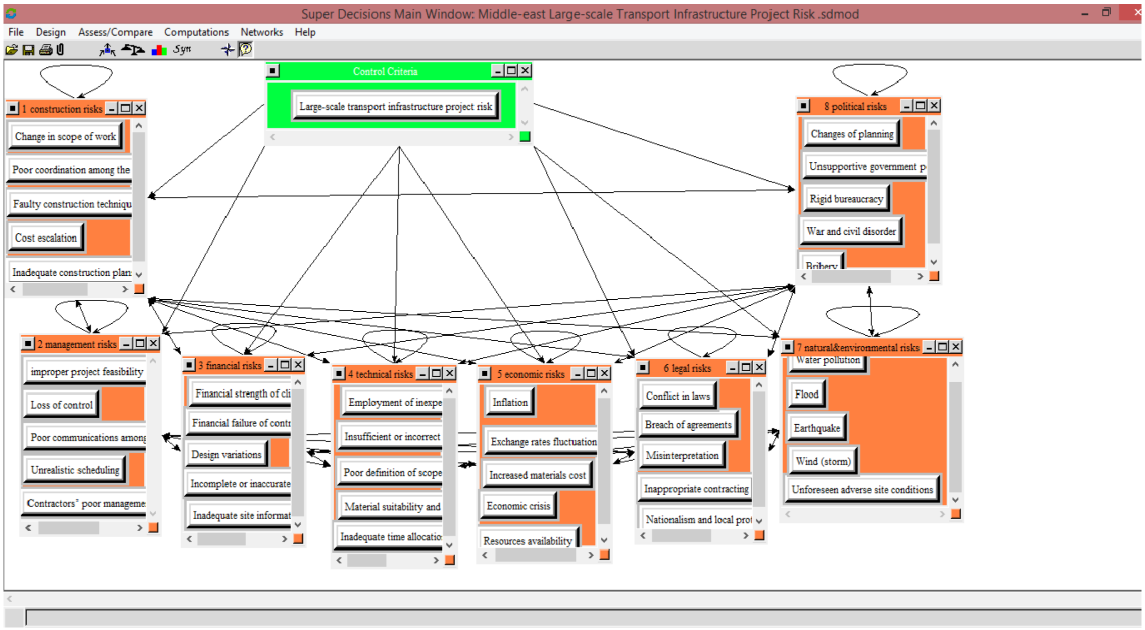


Figure: The Proposed ANP Model for Large-scale Transport Infrastructure Projects in Europe

The Results of the ANP Analysis

Europe risk priorities		
Risk category	Risk factor	Priority (%)
Financial	Financial strength of client	13.37
Financial	Financial failure of contractor	8.71
Financial	Incomplete or inaccurate cost estimate	8.59
Construction	Change in scope of work	5.48
Natural&Environmental	Flood	5.40
Management	Contractors' poor management ability	4.06
Financial	Inadequate site information	3 36
Construction	Inadequate construction planning	3 33
Construction	Cost escalation	3 33
Financial	Design variations	3 19
Economic	Resources availability	2.76
Economic	Increased materials cost	2.76
Management	Loss of control	2.66
Natural&Environmental	Water pollution	2.24
Construction	Poor coordination among the consultants	2.24
Technical	Poor definition of scope	2.18
Natural&Environmental	Unforeseen adverse site conditions	2.02
Natural&Environmental	Earthquake	2.02
Management	Unrealistic scheduling	2.00
Political	Rigid bureaucracy	1.87
Political	War and civil disorder	1.72
Technical	Employment of inexperienced designers	1.63
Construction	Faulty construction techniques	1.54
Management	Poor communications among stakeholders	1.20
Management	improper project feasibility and planning	1.20
Political	Unsupportive government policies	1.15
Legal	Inappropriate contracting	1.14
Natural&Environmental	Wind (storm)	1.11
Economic	Exchange rates fluctuation	1.06
Economic	Economic crisis	1.06
Legal	Breach of agreements	0.86
Political	Changes of planning	0.73
Economic	Inflation	0.71
Technical	Material suitability and accessibility and shortage	0.63
Technical	Insufficient or incorrect design information	0.62
Technical	Inadequate time allocation	0.62
Political	Bribery	0.48
Legal	Nationalism and local protectionism	0.32
Legal	Misinterpretation	0.32
Legal	Conflict in laws	0.32

The tables shows the Priority values of the risk factors under categories

The percentage values represent the priority order of each factor.

Please rate the questions below by considering the LSTIPs-based ANP model and priority values given above *(Select only one option per question)*

Please use the Likert scale table to state the degree of your answer while selecting the options

Table: degree of improvement

Number	Definition
1	Poor
2	Fair
3	Satisfactory
4	Good
5	Excellent

1. To what extent can ANP Model help to assess Construction Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

2. To what extent can ANP Model help to assess Financial Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

3. To what extent can ANP Model help to assess Managerial Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

4. To what extent can ANP Model help to assess Technical Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

5. To what extent can ANP Model help to assess Economic Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

6. To what extent can ANP Model help to assess Legal Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

7. To what extent can ANP Model help to assess Natural and Environmental Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

8. To what extent can ANP Model help to assess Political Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

9. How easy is it to follow the ANP Model?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

10. How useful do you consider the overall ANP Model?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

Appendix F: Evaluation of Analytical Network Process Questionnaire Form for the Middle East Region

Evaluation of Proposed Analytical Network Process Model and Results of Analysis for Large-scale Transport Infrastructure Projects

Dear Sir/Madam, you are kindly invited to voluntarily participate to a survey which has been prepared based on the Analytical Network Process **(**ANP) model and the risk priority results for Large-scale Transport Infrastructure Projects. This survey is a part of the risk assessment process of a PhD study conducted by Fikri Yücelgazi under the supervision of Assoc. Prof. Dr. İbrahim Yitmen in the Department of Civil Engineering at Eastern Mediterranean University in North Cyprus. The target of this survey is to find out to what extent the results of the ANP analysis can improve project risks and to determine the applicability of the proposed ANP model in Large-scale Transport infrastructure projects based on the results of the analysis and ANP model given below for the Middle East region. The survey will take 5 - 10 minutes to complete and your responses will be kept confidential. If you have any questions about this survey, feel free to contact Fikri Yücelgazi via fikri.yucelgazi1@gmail.com .Your participation and feedback is highly appreciated. Thank you for your time and cooperation.

Analytical Network Process

An ANP - an effective and realistic solution for complex decision making problems - was introduced in 1996 by Thomas L. Saaty. ANP is defined as a MCDM that takes the qualitative values as well as the quantitative values into consideration and models the problem in a hierarchical structure and takes into account the relationships and interactions between the modelling criteria.

There are eight categories and forty risk factors in this model.

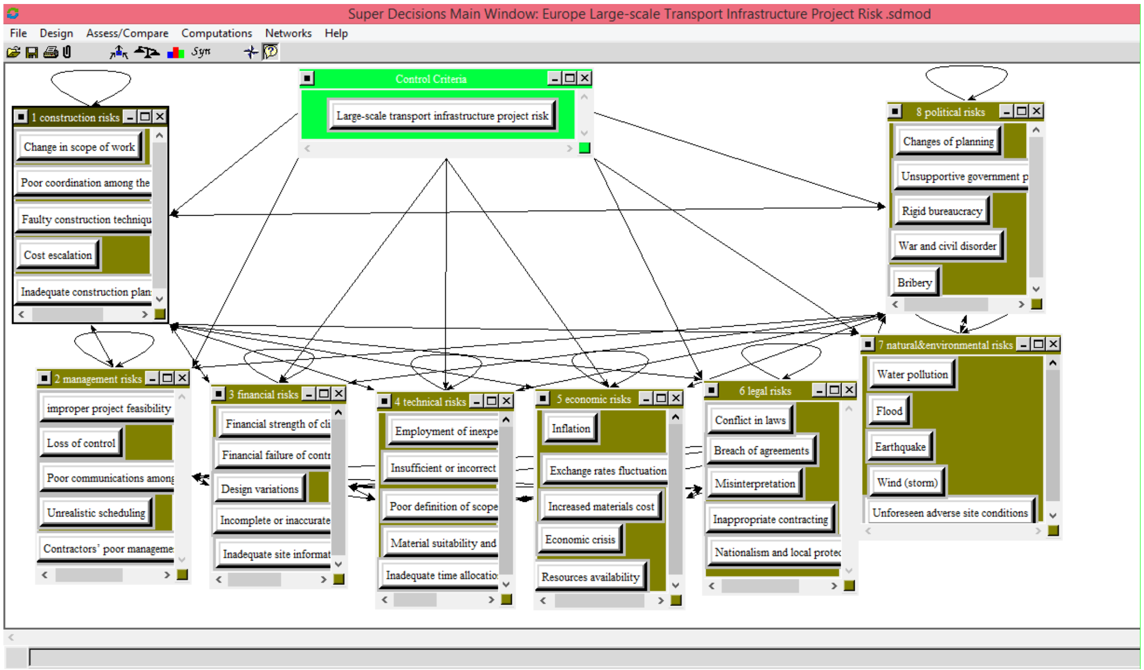


Figure: The Proposed ANP Model for Large-scale Transport Infrastructure Projects in the Middle East

The Results of ANP Analysis

The table shows the Priority values of the risk factors under categories

Middle East risk priorities		
Risk category	Risk factor	Priority (%)
Financial	Financial strength of client	11.54
Financial	Financial failure of contractor	11.10
Financial	Incomplete or inaccurate cost estimate	7.87
Natural&Environmental	Water pollution	4.55
Financial	Inadequate site information	4.34
Management	Loss of control	4.28
Management	Contractors' poor management ability	4.14
Construction	Change in scope of work	4.14
Construction	Cost escalation	4.14
Construction	Faulty construction techniques	4.14
Political	Unsupportive government policies	3.62
Economic	Increased materials cost	2.91
Economic	Resources availability	2.81
Natural&Environmental	Earthquake	2.45
Natural&Environmental	Flood	2.45
Natural&Environmental	Wind (storm)	2.45
Financial	Design variations	2.37
Technical	Poor definition of scope	2.33
Construction	Poor coordination among the consultants	2.20
Legal	Inappropriate contracting	1.79
Construction	Inadequate construction planning	1.31
Economic	Economic crisis	1.29
Technical	Employment of inexperienced designers	1.25
Technical	Material suitability and accessibility and shortage	1.25
Political	Rigid bureaucracy	1.25
Management	improper project feasibility and planning	1.00
Management	Poor communications among stakeholders	0.98
Natural&Environmental	Unforeseen adverse site conditions	0.89
Economic	Exchange rates fluctuation	0.87
Management	Unrealistic scheduling	0.71
Legal	Breach of agreements	0.53
Economic	Inflation	0.49
Political	Changes of planning	0.48
Technical	Inadequate time allocation	0.42
Technical	Insufficient or incorrect design information	0.42
Legal	Nationalism and local protectionism	0.32
Political	Bribery	0.31
Political	War and civil disorder	0.30
Legal	Conflict in laws	0.16
Legal	Misinterpretation	0.16

The percentage values represents the priority order of the each factor.

Please rate questions below by considering the LSTIPs-based ANP model and Priority values given above *(Select only one option per question)*

Please use the Likert scale table to state the degree of your answer while marking the options

Table: degree of improvement

Number	Definition
1	Poor
2	Fair
3	Satisfactory
4	Good
5	Excellent

1. To what extent can ANP Model help to assess Construction Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

2. To what extent can ANP Model help to assess Financial Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

3. To what extent can ANP Model help to assess Managerial Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

4. To what extent can ANP Model help to assess Technical Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

5. To what extent can ANP Model help to assess Economic Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

6. To what extent can ANP Model help to assess Legal Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

7. To what extent can ANP Model help to assess Natural and Environmental Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

8. To what extent can ANP Model help to assess Political Risks?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

9. How easy is it to follow the ANP Model?

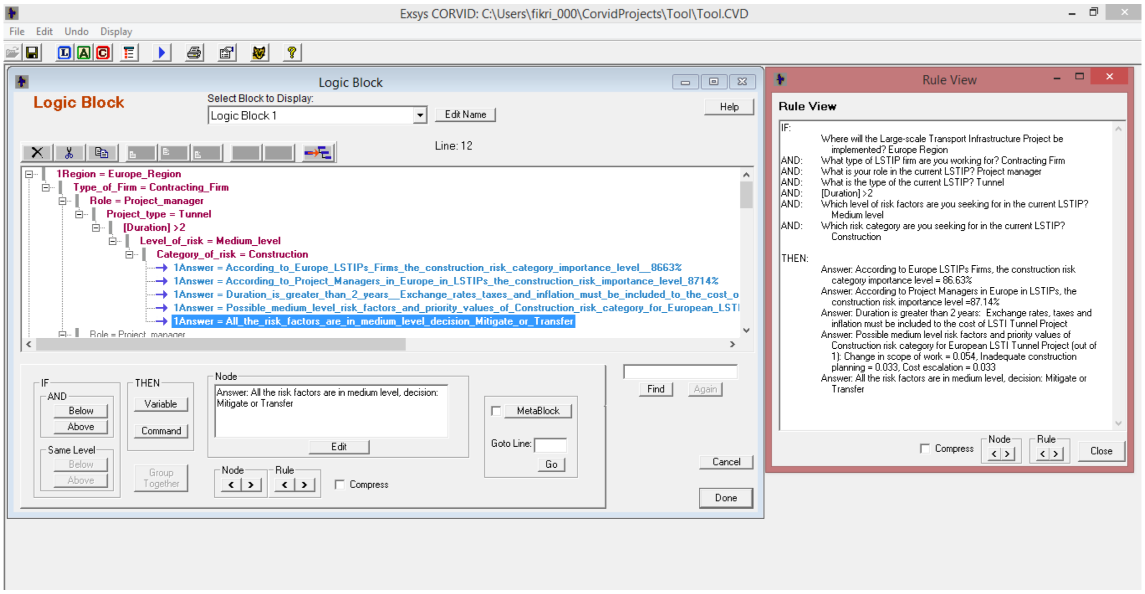
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

10. How useful do you consider the overall ANP Model?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

Appendix G: LSTIPs' Risk Identification and Decision Supporting Tool Rules Logic Block

Logic Block 1



Source: The process followed by the author

The Logic Block displayed above is equivalent to the following rules:

Logic block1

IF:

Where will the Large-scale Transport Infrastructure Project be implemented? Europe Region

AND: What type of LSTIP firm are you working for? Contracting Firm

AND: What is your role in the current LSTIP? Project manager

AND: What is the type of the current LSTIP? Tunnel

AND: [Duration] >2

AND: Which level of risk factors are you seeking for in the current LSTIP? Medium level

AND: Which risk category are you seeking for in the current LSTIP?

Construction

THEN:

Answer: According to Europe LSTIPs Firms, the construction risk category importance level = 86.63%

Answer: According to Project Managers in Europe in LSTIPs, the construction risk importance level =87.14%

Answer: Duration is greater than 2 years: Exchange rates, taxes and inflation must be included to the cost of LSTI Tunnel Project

Answer: Possible medium level risk factors and priority values of Construction risk category for European LSTI Tunnel Project (out of 1): Change in scope of work = 0.054, Inadequate construction planning = 0.033, Cost escalation = 0.033

Answer: All the risk factors are in medium level, decision: Mitigate or Transfer

IF:

Where will the Large-scale Transport Infrastructure Project be implemented? Europe Region

AND: What type of LSTIP firm are you working for? Contracting Firm

AND: What is your role in the current LSTIP? Project manager

AND: What is the type of the current LSTIP? Tunnel

AND: [Duration] <2

AND: Which level of risk factors are you seeking for in the current LSTIP?

Medium level

AND: Which risk category are you seeking for in the current LSTIP?

Construction

THEN:

Answer: According to Europe LSTIPs Firms, the construction risk category importance level = 86.63%

Answer: According to Project Managers in Europe in LSTIPs, the construction risk importance level =87.14%

Answer: Duration is less than 2 years: Exchange rates and taxes must be included to the cost of LSTI Tunnel Project

Answer: Possible medium level risk factors and priority values of Construction risk category for European LSTI Tunnel Project (out of 1): Change in scope of work = 0.054, Inadequate construction planning = 0.033, Cost escalation = 0.033

Answer: All the risk factors are in medium level, decision: Mitigate or Transfer

IF:

Where will the Large-scale Transport Infrastructure Project be implemented? Europe Region

AND: What type of LSTIP firm are you working for? Contracting Firm

AND: What is your role in the current LSTIP? Project manager

AND: What is the type of the current LSTIP? Tunnel

AND: [Duration] >2

AND: Which level of risk factors are you seeking for in the current LSTIP? High level

AND: Which risk category are you seeking for in the current LSTIP? Construction

THEN:

Answer: According to Europe LSTIPs' Firms, the construction risk category importance level = 86.63%

Answer: According to Project managers in Europe in LSTIPs, Construction category importance level = 87.14%

Answer: Duration is greater than 2 years: Exchange rates, taxes and inflation must be included to the cost of LSTI Tunnel Project

Answer: No high level risk factor is encountered in the construction risk category for Europe LSTI Tunnel Project

Answer: If any high level of risk factor is encountered for Europe LSTI Tunnel Project, accept the risk

IF:

Where will the Large-scale Transport Infrastructure Project be implemented? Europe Region

AND: What type of LSTIP firm are you working for? Contracting Firm

AND: What is your role in the current LSTIP? Project manager

AND: What is the type of the current LSTIP? Tunnel

AND: [Duration] <2

AND: Which level of risk factors are you seeking for in the current LSTIP? High level

AND: Which risk category are you seeking for in the current LSTIP? Construction

THEN:

Answer: According to Europe LSTIPs' Firms, the construction risk category importance level = 86.63%

Answer: According to Project managers in Europe in LSTIPs, Construction category importance level = 87.14%

Answer: Duration is less than 2 years: Exchange rates and taxes must be included to the cost of LSTI Tunnel Project

Answer: No high level risk factor is encountered in the construction risk category for Europe LSTI Tunnel Project

Answer: If any high level of risk factor is encountered for Europe LSTI Tunnel Project, accept the risk

IF:

Where will the Large-scale Transport Infrastructure Project be implemented? Europe Region

AND: What type of LSTIP firm are you working for? Contracting Firm

AND: What is your role in the current LSTIP? Project manager

AND: What is the type of the current LSTIP? Tunnel

AND: [Duration] >2

AND: Which level of risk factors are you seeking for in the current LSTIP? Low level

AND: Which risk category are you seeking for in the current LSTIP? Construction

THEN:

Answer: According to Europe LSTIPs Firms, the construction risk category importance level = 86.63%

Answer: According to Project Managers in Europe in LSTIPs, the financial risk importance level =87.14%

Answer: Duration is greater than 2 years: Exchange rates, taxes and inflation must be included to the cost of LSTI Tunnel Project

Answer: No low level risk factor is encountered in the construction risk category for Europe LSTI Tunnel Project

Answer: If any low level of risk factor is encountered for Europe LSTI Tunnel Project: eliminate or neglect

IF:

Where will the Large-scale Transport Infrastructure Project be implemented? Europe Region

AND: What type of LSTIP firm are you working for? Contracting Firm

AND: What is your role in the current LSTIP? Project manager

AND: What is the type of the current LSTIP? Tunnel

AND: [Duration] <2

AND: Which level of risk factors are you seeking for in the current LSTIP? Low level

AND: Which risk category are you seeking for in the current LSTIP? Construction

THEN:

Answer: According to Europe LSTIPs Firms, the construction risk category importance level = 86.63%

Answer: According to Project Managers in Europe in LSTIPs, the financial risk importance level =87.14%

Answer: Duration is less than 2 years: Exchange rates and taxes must be included to the cost of LSTI Tunnel Project

Answer: No low level risk factor is encountered in the construction risk category for Europe LSTI Tunnel Project

Answer: If any low level of risk factor is encountered for Europe LSTI Tunnel Project: eliminate or neglect

Logic block 2

IF:

Where will the Large-scale Transport Infrastructure Project be implemented? Middle East Region

AND: What type of LSTIP firm are you working for? Contracting Firm

AND: What is your role in the current LSTIP? Construction Manager

AND: What is the type of the current LSTIP? Bridge

AND: [Duration] >2

AND: Which level of risk factors are you seeking for in the current LSTIP? High level

AND: Which risk category are you seeking for in the current LSTIP? Financial

THEN:

Answer: According to Middle East LSTIPs Contracting Firms, the Financial risk category importance level = 91.30%

Answer: According to Construction Managers in Middle East in LSTIPs, the financial risk importance level =88.28%

Answer: Duration is greater than 2 years: Exchange rates, taxes and inflation must be included to the cost of LSTI Bridge Project

Answer: Possible High level risk factors and priority values of Financial risk category for European LSTI Bridge Project (out of 1): Financial strength of client = 0.115, Financial failure of contractor = 0.110

Answer: All the risk factors are in High level, decision: Accept

IF:

Where will the Large-scale Transport Infrastructure Project be implemented? Middle East Region

AND: What type of LSTIP firm are you working for? Contracting Firm

AND: What is your role in the current LSTIP? Construction Manager

AND: What is the type of the current LSTIP? Bridge

AND: [Duration] <2

AND: Which level of risk factors are you seeking for in the current LSTIP? High level

AND: Which risk category are you seeking for in the current LSTIP? Financial

THEN:

Answer: According to Middle East LSTIPs Contracting Firms, the Financial risk category importance level = 91.30%

Answer: According to Construction Managers in Middle East in LSTIPs, the financial risk importance level =88.28%

Answer: Duration is less than 2 years: Exchange rates and taxes must be included to the cost of LSTI Bridge Project

Answer: Possible High level risk factors and priority values of Financial risk category for European LSTI Bridge Project (out of 1): Financial strength of client = 0.115, Financial failure of contractor = 0.110

Answer: All the risk factors are in High level, decision: Accept

IF:

Where will the Large-scale Transport Infrastructure Project be implemented? Middle East Region

AND: What type of LSTIP firm are you working for? Contracting Firm

AND: What is your role in the current LSTIP? Construction Manager

AND: What is the type of the current LSTIP? Bridge

AND: [Duration] >2

AND: Which level of risk factors are you seeking for in the current LSTIP? Medium level

AND: Which risk category are you seeking for in the current LSTIP? Financial

THEN:

Answer: According to Middle East LSTIPs Contracting Firms, the Financial risk category importance level = 91.30%

Answer: According to Construction Managers in Middle East in LSTIPs, the financial risk importance level =88.28%

Answer: Duration is greater than 2 years Exchange rates, taxes and inflation must be included to the cost of LSTI Bridge Project

Answer: Possible Medium level risk factors and priority values of Financial risk category for the Middle Eastern LSTI Bridge Project (out of 1): Incomplete or inaccurate cost estimate = 0.078

Answer: All the risk factors are in medium level, decision: Mitigate or Transfer

IF:

Where will the Large-scale Transport Infrastructure Project be implemented? Middle East Region

AND: What type of LSTIP firm are you working for? Contracting Firm

AND: What is your role in the current LSTIP? Construction Manager

AND: What is the type of the current LSTIP? Bridge

AND: [Duration] <2

AND: Which level of risk factors are you seeking for in the current LSTIP? Medium level

AND: Which risk category are you seeking for in the current LSTIP? Financial

THEN:

Answer: According to Middle East LSTIPs Contracting Firms, the Financial risk category importance level = 91.30%

Answer: According to Construction Managers in Middle East in LSTIPs, the financial risk importance level =88.28%

Answer: Duration is less than 2 years: Exchange rates and taxes must be included to the cost of LSTI Bridge Project

Answer: Possible Medium level risk factors and priority values of Financial risk category for the Middle Eastern LSTI Bridge Project (out of 1): Incomplete or inaccurate cost estimate = 0.078

Answer: All the risk factors are in medium level, decision: Mitigate or Transfer

IF:

Where will the Large-scale Transport Infrastructure Project be implemented? Middle East Region

AND: What type of LSTIP firm are you working for? Contracting Firm

AND: What is your role in the current LSTIP? Construction Manager

AND: What is the type of the current LSTIP? Bridge

AND: [Duration] >2

AND: Which level of risk factors are you seeking for in the current LSTIP? Low level

AND: Which risk category are you seeking for in the current LSTIP? Financial

THEN:

Answer: According to Middle East LSTIPs Contracting Firms, the Financial risk category importance level = 91.30%

Answer: According to Construction Managers in Middle East in LSTIPs, the financial risk importance level =88.28%

Answer: Duration is greater than 2 years: Include exchange rates, taxes and inflation must be included to the cost of LSTI Bridge Project

Answer: Possible low level risk factor and priority value of the financial risk category for Middle Eastern LSTI Bridge Project (out of 1): Design variations = 0.023

Answer: Decision: Eliminate or Neglect the risk

IF:

Where will the Large-scale Transport Infrastructure Project be implemented? Middle East Region

AND: What type of LSTIP firm are you working for? Contracting Firm

AND: What is your role in the current LSTIP? Construction Manager

AND: What is the type of the current LSTIP? Bridge

AND: [Duration] <2

AND: Which level of risk factors are you seeking for in the current LSTIP?
Low level

AND: Which risk category are you seeking for in the current LSTIP? Financial

THEN:

Answer: According to Middle East LSTIPs Contracting Firms, the Financial risk category importance level = 91.30%

Answer: According to Construction Managers in Middle East in LSTIPs, the financial risk importance level =88.28%

Answer: Duration is less than 2 years: Exchange rates and taxes and inflation must be included to the cost of LSTI Tunnel Project

Answer: Possible low level risk factor and priority value of the financial risk category for Middle Eastern LSTI Bridge Project (out of 1): Design variations = 0.023

Answer: Decision: Eliminate or Neglect the risk