

RISK ASSESSMENT FOR AIRPORT CONSTRUCTION PROJECTS BASED ON  
THE EXPERIENCE OF PROJECT MANAGERS

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## **Abstract**

### **RISK ASSESSMENT FOR AIRPORT CONSTRUCTION PROJECTS BASED ON THE EXPERIENCE OF PROJECT MANAGERS**

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Considering the fact that the majority of the contractor's face difficulties and problems while dealing with risks and uncertainties which lead not only to financial losses, but also to motivational and reputation damages; the need of developing knowledge of risk management in construction industry becomes essential. This risk management study focuses on the airport construction projects (ACPs) which are designed not to have only terminal building with its ancillary buildings, but also to have hotels, conference halls and recreation areas which make them to be distinguished from the others. High interaction between the stakeholders like investors, contractors, consultants, suppliers, employees, travelers, customers who are interested in airport retail areas reinforces this need. Contribution to the literature which suffers lack of risk-related studies on ACPs is the other motivation of this study by which it is aimed to guide project managers who are willing to work for ACPs for the risks and risk management methods.

For the purpose of analyzing the risks in ACPs, semi-structured interviews were conducted with the experienced company managers, project directors and managers, consultants, department leaders, and prominent subcontractors' representatives. The results of the semi-structured interviews were assessed by Analytic Network Process (ANP) since it is easier and more convenient method than other risk assessment methods to apply for numerous criteria and assessing the results comparing to others. The results of this technique applied are reported to enlighten the ways of project managers and other stakeholders for the risks in ACPs.

*Keywords:* Risk management, airport construction projects, semi-structured interviews, Analytic Network Process

## Öz

# PROJE YÖNETİCİLERİ TECRÜBELERİNE GÖRE HAVALİMANI İNŞAATI PROJELERİ İÇİN RİSK DEĞERLENDİRMESİ

Tiryaki, Ahmet Gokhan

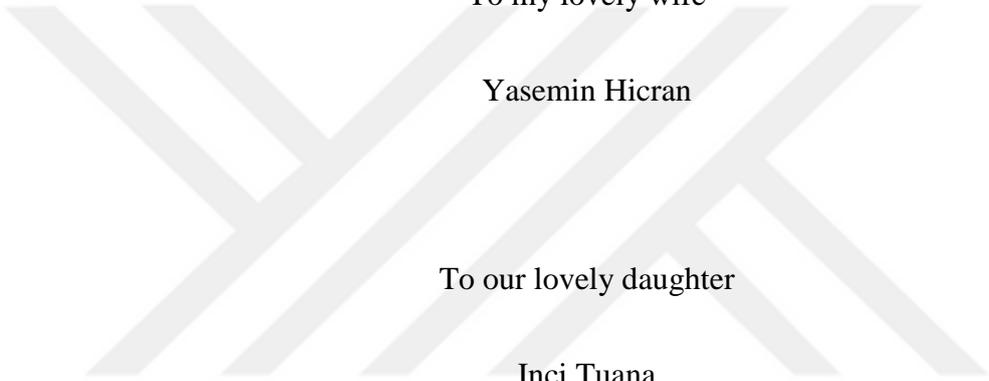
Tez Yöneticisi: Sait Metin Arıkan

Mart 2019

İnşaat sektöründe faaliyet gösteren yüklenici firmaların, üstlendikleri projelerde en fazla çabayı finansal kayıpların yanı sıra motivasyon ve itibar kayıplarına da sebep olabilen riskler ve belirsizliklerle mücadele ederken sarfettikleri göz önünde tutulduğunda, inşaat sektöründeki riskleri ele alan bir risk değerlendirme çalışması gerekliliği ortaya çıkmıştır. Bu risk yönetimi çalışmasında; otel, konferans salonları, katlı otopark gibi yapılarla çeşitli aktivite ve fonksiyonlara olanak sağlamak üzere tasarlanan ve servis sağlayıcılarından havayolu şirketlerine, havalimanını kullanacak yolculardan yerel yönetimlere kadar geniş bir paydaş grubuyla etkileşim halinde olan havalimanı inşaatı projeleri baz alınmıştır. Bununla birlikte, literatürde havalimanı inşaatı projelerinde risk yönetimi konusu üzerine yeterli çalışma bulunmaması, bu çalışmaya olan ihtiyacı pekiştirmiştir. Bu çalışmanın havalimanı inşaatı projelerinde görev alacak yüklenici, alt yüklenici ve danışman gibi geniş paydaş grubuna, projenin inşaat aşamasında karşılaşılabilecekleri risklere yönelik risk belirleme, analiz etme ve anlamaya ışık tutması amaçlanmıştır.

Havalimanı inşaatı projelerinin risklerini analiz etmek amacıyla önce firma yöneticileri, proje direktör ve müdürleri, danışmanlar, farklı departmanların yöneticileri, önde gelen alt yüklenici firmalarının temsilcileri ile yarı yapılandırılmış mülakatlar yapılmıştır. Yarı yapılandırılmış mülakatlardan çıkan sonuçlar Analitik Ağ Süreci (ANP) metodu ile değerlendirilmiştir. Bu metot çok sayıda kriterle başa çıkabilmede ve sonuçları değerlendirmede diğer metotlara göre daha uygulanabilirdir.

*Anahtar kelimeler:* Risk yönetimi, havalimanı inşaatı projeleri, yarı yapılandırılmış mülakatlar, Analitik Ağ Süreci



To my lovely wife

Yasemin Hicran

To our lovely daughter

Inci Tuana

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## **List of Abbreviations**

ACP(s)	: Airport Construction Project(s)
AHP	: Analytic Hierarchy Process
ANP	: Analytic Network Process
CR	: Consistency Ratio
EC	: European Commission
FIFA	: Fédération Internationale de Football Association
PPP	: Public Private Partnership
FOD	: Foreign Object Damage
HIST	: Historical Data
HSE	: Health, Safety & Environment
ILO	: International Labor Organization
MEP	: Mechanical, Electrical, Plumbing
OECD	: Organization for Economic Cooperation and Development
RM	: Risk Management
WHO	: World Health Organization

## **1. Introduction**

Agriculture and construction can be named as the oldest industries in human civilization. Without any doubt, humans executed some, even little, construction activities to make their caves suitable for their needs. Construction projects are likely to have become a matter of business before building the pyramids in Egypt with the concepts of risks and uncertainties (Simu, 2006). Furthermore, the various risks and uncertainties still exist in the construction industry, even getting more complicated compared to the ancient times, and they need to be carefully studied so that a better and successful project management takes place.

However, the very first studies on risk management were conducted very late, after Second World War. It is indicated that the modern approaches on risk management studies have been started to be executed from 1955 to 1964 (Crockford, 1982 and Harrington and Niehaus, 2003). The first two books, about pure risk management, were published in 1963 (Dionne, 2013).

Considering the construction sector, risk management was firstly stated during the first half of 1980s. During these initial studies on risk management on construction industry, the “risk engineering” concept was defined by Chapman and Cooper (1983) integrated with its different tools and techniques (Taroun et al., 2011).

Majority of the contractor’s face problems and difficulties in coping with uncertainties and risks that not only result financial damages, but also cause reputational and motivational losses. Therefore, development of risk management knowledge becomes crucial to handle the risks.

Prior to handling the risks, the risk identification study is needed to enlighten the ways of the contractors. Knowing the fact that all risks in construction projects are not evitable, the contractors may choose identification of the most critical risk factors which may cause failures or economical and reputational losses to them.

The goal of this study is to look in detail to risk categories and subcategories by usage of semi-structured interviews and to generate a network model which helps contractors to figure out most critical risks for airport construction projects.

## 1.1. Brief Description on Risk

Barkley T.B. (2004) defines project risk management (RM) as an art, but not a science. Besides, risks are simply inevitable components of the daily life. Relating to the risks, the target of risk management is to rise the chance of occurrence of the internal/external positive risks (opportunities) and to reduce the probability of the internal/external negative risks (threads) (Hazir, 2014).

After defining the risk as a simple concept of a thinking way throughout a project, Barkley (2004) indicated some principles underlying the definition of the risk:

- i. Risk is an inseparable part of the management concept. Therefore, it is not wrong to say that there would not be a project if there were no risk.
- ii. Projects have many risks in them and RM aims to identify the critical ones and holds the main idea of controlling them. Besides, the opportunities are the positive risks which lead to better, faster, and cheaper production of its deliverables and satisfying investor needs.
- iii. Since projects have many risks in them, dealing with all of them is not easy. Therefore, project managers often focus only on the high-impact-risks and/or resource-consuming tasks.
- iv. Risk monitoring is a matter of identifying key risks to support decision makers during their studies.
- v. Understanding the risks with their probable influences on project leads the one to the stage of planning risk response.

Risk management (RM) is defined to be a process which starts with planning risk management and continuing with identifying risks, performing analysis by qualitative and/or quantitative techniques, accordingly, planning their responses and monitoring and controlling them (PMBOK, 2000). During these steps, risks shall be monitored and controlled by the project managers. Figure 1 illustrates the concept of risk management plan and its components.

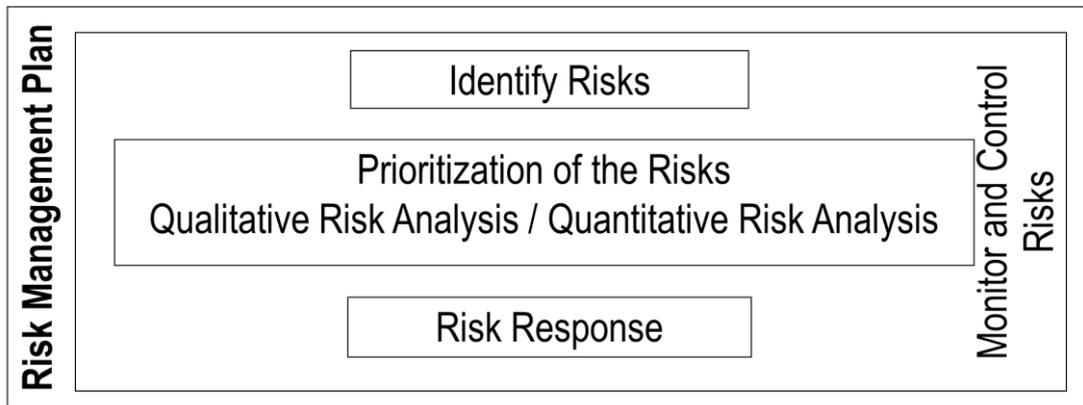


Figure 1 – Risk management plan

## 1.2. Airport Construction Projects (ACPs) in Brief

With the high investment level, the airports have a great effect on the economy and the development of the region where they are located (Alnasseri, Osborne and Steel, 2013). Besides, the airports have recently been constructed to be a core of the transportation web with their ancillary buildings around to meet the growth of public and passenger needs (Binnekade, Biciocchi, O'Rourke, and Vincent, 2009).

It is good to know more about the ACPs prior to going into its details. The following explanations will provide a better understanding of them, and the reasons behind the aim of the study.

Various Activities and Functions: Beyond any doubt, the development in technology brought the requirement of an extended transportation network. The decision makers usually carry this requirement one step further and try to make the travelling more attractive. Because of this reason, the designs of airports nowadays are developed to have passenger terminal building and its facilities such as electromechanical service buildings, water tank buildings, etc. but also to have recreation areas, conference halls and hotels in them. In addition to those mentioned above with the safe areas, airside works such as aprons and runways, special airport systems such as baggage handling and aviation fuel hydrant systems, mostly multistory car parking buildings and landscaping and irrigation requirements make the airport construction projects to be distinguished from the others.

Safety Rules and Regulations: In construction industry, these rules and regulations are very common. However, understanding of safety rules and regulations differs for an airport construction, and an operational airport expansion project. This makes the project managers take required precautions not to affect the safety of the aircrafts and the airside.

Many Stakeholders: Considering ACPs, stakeholders can be listed including investors, contractors, subcontractors, consultants, vendors and suppliers, employees and workers. This huge group has a great internal interaction. Elliot, Chapman and Kelly (2015) help to extend this list considering an operational airport, and list customers, travelers, who most likely be interested in airport retail areas, the public next to the airports, base operators, airline operators and their workers, government and airport dwellers, etc. as the stakeholders. This long list provides a hint that the level of direct and indirect interactions between the stakeholders may lead to certain human-related or system-related risks on ACPs. The following figure represents a communication network sample for airports of which the construction stage takes place in the middle. Therefore, the ACPs might be considered to be in the middle of the stakeholder interaction diagram, as shown in Figure 2.

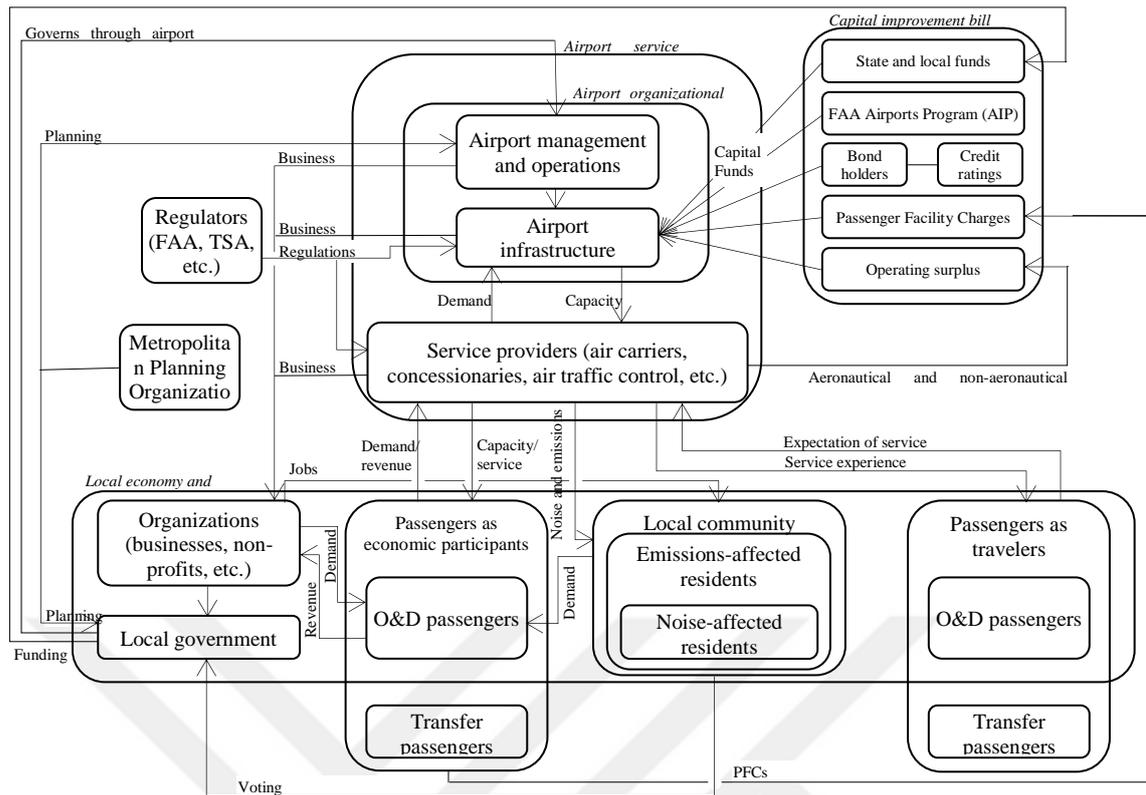


Figure 2 – A sample stakeholder relationship diagram (Schaar and Sherry, 2010)

High Level of Impact: Even though it is not the subject of this study, it is good to touch on the impacts of airport construction projects which can be described as short-term and temporary in nature. Air pollution, water pollution, and noise pollution can be counted as typical impacts of ACPs considering environmental aspects. In addition, increasing amount of hazardous and solid wastes during ACPs generates potential impacts.

Furthermore, ACPs are important as they provide significant economic benefits to the country. They ensure a high level of local and international direct (such as technical staff and worker) and indirect (such as service suppliers) employment. For Austin-Bergstrom International Airport Project, Echeverri-Caroll (1999) states that the predictions were to create more than 11,000 new job opportunities for the airport construction project held in City of Austin, of which roughly fifty percent was direct employment. For the same project, Austin-Bergstrom International Airport Project, by the year of 2012, the number of the employment, including indirect and direct, was expected to exceed 16,000. Moreover, in the City of Austin, more than 65,000 m<sup>2</sup> of new facilities (such as office spaces, hotels, and retail spaces) estimated to be added to

the area around the new airport as a result of the development in residential and commercial needs, affiliated with the new airport (Echeverri-Caroll, 1999).

Critical Time Frame: Most of the countries decide constructing or expanding an airport because of increasing demands in the air traffic. Another reason behind such a decision is also likely to become an attraction center in tourism, business or transition center in the air traffic web. Fortunately, the decision makers' intent is to meet future demands by expansion projects of the current airports, or by construction of new ones, as quickly as possible. It should for sure be quick since they would not wish to deal with opportunity costs caused by any kind of delay in completion time of the ACPs. In some special circumstances, such as World and Olympic Games, push the schedule of airport construction project to be extremely crucial (Alnasseri, Osborne and Steel, 2013). Russia's airport preparations for 2018 FIFA World Cup and Qatar's airport preparations for 2022 FIFA World Cup can be given as examples of such needs.

Figure 3 shows the above-mentioned parameters of the airport construction projects which make them to be considered as a special case in construction sector.

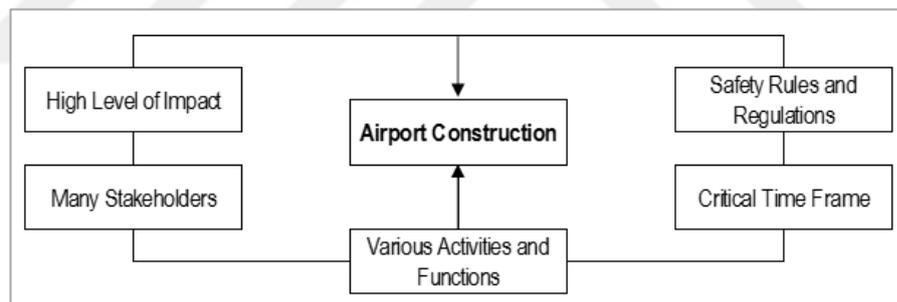


Figure 3 – Parameters affecting airport construction projects (Alnasseri, Osborne and Steel, 2013)

### 1.3. Motivation of the Study: Risks in ACPs

Apart from managing projects in a perfect way in terms of time, quality, scope and budget, there is no doubt that distinguished project managers are the ones who are able to transform risks to opportunities with a great understanding in legal, sociopolitical aspects of ACPs with practices of ethics. Again, successful project managers are good at preventing and solving conflicts between project stakeholders. Besides, project

managers should be open to adaptations to changes in social, environmental and business aspects.

In the previous chapter, the attributes of the airport and the reasons why the ACPs can be distinguished from the other types of construction were explained. One can predict that the ACPs bring associated risks with the parameters mentioned above, and those risks need to be identified and analyzed carefully to avoid unwanted risk related damages. There is not enough information on construction risk analysis (Taroun and Yang, 2013) and lack of literature regarding risks in the ACPs (Baghdadi and Kishkleads, 2015) bring troubles for the companies who are willing to participate in the formerly mentioned projects. This study aims to identify the major risks in airport construction projects and contribute to the literature by closing this gap. Another goal of this study will be to analyze those identified risks by suitable qualitative approaches which will be explained in the coming chapters in detail. By this study, an establishment of a guideline for understanding, identifying and analyzing risks regarding the airport construction projects is also aimed for the decision makers who pursue to be distinguished in terms of the aspects highlighted in the previous paragraph.

## 2. Literature Overview

Literature reviews for risk management and assessment issues of construction projects have been carried out. In the coming lines, the findings of the literature overview are summarized:

Wideman, R.M. (1992) explains risk management sequence. The fundamental target of his book is to create a handbook on RM for large projects. However, the book guides to project managers to have a successful risk management knowledge for large or small, complex or simple projects (Wideman, 1992). He believes that in the future applications, simulation techniques by computer applications will widely be used as certain softwares include large databases allowing to what-if scenarios.

The “Project Risk Management” book (Raydugin, 2013) raised the definition of risks. According to Raydugin (2013) project managers are supposedly to face risks in their business. The author applied deterministic and probabilistic methods, like Monte Carlo Methods, for problem solving. Being experienced in mega projects (Raydugin, 2013), the author has shown efficient solution methods about project risks. The book also covers a case study concluded by applications of deterministic and probabilistic methods with what-if scenarios.

In the book titled “Project Risk Management”, Barkley T.B. (2004) has started with definition of risk. Besides, he raised a new term: demystification which involves some new assumptions about project planning and control. Referring to PMI, the author widened the risk analysis methods which are qualitative and quantitative methods (Barkley, 2004). Besides, the author also introduced another term: Risk Matrix and explained the risk items on a hiring project in detail.

Project Management Institute, Inc. published the book titled “Practice Standard for Project Risk Management” in 2009 starting with a sharp definition: “All projects are uncertain.” (Practice Standard for Project Risk Management, 2009) which is more or less true, and continued with other definitions in accordance with PMI way of handling the other management-related subjects:

- Plan Risk Management: Developing the overall risk management strategy for a project.

- Identify Risks: A risk first should be identified to be managed properly.
- Qualitative Risk Analysis: The identified risks need to be categorized according to their characteristics.
- Quantitative Risk Analysis: Applied when a numerical estimate is needed to be provided to contribute RM procedures of the project.
- Plan Risk Responses: The requirement of setting a response plan arises after the risks are identified and analyzed.
- Monitor and Control Risks: The response plans require to be monitored and controlled to ensure the effective usage of RM applications.

Baccarini and Archer (2001) prepared their article about Australian projects by using the methodology of risk ranking. Cost, time and quality were the considerations for the authors while dividing the project-related-risks into subcategories. For this study, project managers scored every parameter in the risk-reflecting-tables. By this way, the required inputs have been generated for usage of software. Then the authors applied a computer program to calculate the risk scores for the project (Baccarini and Archer, 2001).

In their study, Baghdadi and Kish (2015) reached the information by literature overview, interviewing with clients, contractors and consultants aiming to identify risks. Similarly, they have selected an aviation subject. However, they have narrowed their study by Saudi Arabian projects. They applied Analytic Hierarchy Process (AHP) to get results. Finally, the authors reached 54 identified risks among which 5 most common and important risks (Baghdadi and Kish, 2015).

A study under the title of “An Analytical Network Process model for risks prioritization in megaprojects” was prepared by Boateng, Chen, and Ogunlana (2014) with the aims of identifying and describing significant risks, developing a framework and prioritizing them across the entire set of STEEP (social, technical, economic, environmental and political) issues for mega projects at their construction stage. Data was gathered by literature overview, source documents of past and similar projects and other case studies. As the title also implies, the method of Analytical Framework was applied. As a result of the study, Analytical Network Process (ANP) was used to assess and prioritize impacts of the risks (Boateng, Chen and Ogunlana, 2014).

Taroun and Yang (2013) published a paper on a Dempster-Shafer-Theory-based approach for structuring the experiences of the individuals and obtaining expert judgment when assessing the risks on construction projects. The aim of the study was to contribute a bridge for the void between RM theory and its practice in construction projects. After collecting data from literature and experts by their professional experiences and personal judgments, the authors applied DST and ER (Evidential Reasoning) methods. Fortunately, the results of their study showed that DST and ER approaches could introduce a good alternative to help risk analysis in the area of construction management (Taroun and Yang, 2013)

In Creative Construction Conference held in 2015, Toth, T. and Sebestyen, Z. issued their study (2015). The objective of the study was to introduce an evaluation method and to provide risk monitoring tool. They chose reviewing literature to get information for their study and applied holistic risk management method moving from a fragmented methodology to integrated and broadly focused on a value-based risk management approach, named Handled Capital Budgeting Theory. As a result, they indicate that further understanding and clarification of project risks can be achieved by their risk monitoring process in which the mathematical context of time-varying application is applied.

With the objective of understanding risks and managing them in complicated projects, an article was published by Miller, R. and Lessard, D. (2001). In the lights of the information gathered from the literature, the authors applied qualitative methods to come up the result that economic value of the projects are usually seems to be higher compared to their discounted present values for future cash flows (Miller and Lessard, 2001).

Nooter, H. prepared his master thesis on “Risk Profiles of Infrastructure Projects at the Public Party” in Delft University of Technology (2014). He investigated a qualitative comparative analysis of risk profiles of Dutch infrastructure projects with an aim of determining risk profiles in them. He basically used literature and historical data to reach the information he needed. Complexity phenomenon of the projects according to the risk identification were explained in his master thesis by application of qualitative analysis (Nooter, 2014).

After Creative Construction Conference held in 2015, another study was published by Nical, A.K. and Wodynski, W. under the title of “Procuring governmental megaprojects: Case study”. Authors used project objectives and priorities, as well as client attitude to risk to collect data based on Kraków Olympic Village Project. Establishment of a strategic approach to procurement on large-scale governmental investment projects was aimed in this study and the authors applied qualitative risk analysis and what-if analysis to get the result of that procurement strategy should be custom-made to satisfy the project requirements considering of all involved stakeholders’ needs (Nical and Wodynski, 2015).

Dikmen, Birgonul and Arikan (2015) published an academic paper which groups risk management researches in different categories:

1. Framework development and model generation process systematic RM
2. Identification of the risks, trends in RM
3. Introducing the risk identification and risk analysis tools in certain projects
4. Generation of integrated RM support tools

The authors listed 21 commercial risk management softwares including Predict!Risk Controller by Risk Decisions, RiskID Pro by KLCI, CRIMS by Expert choice, Crystal Ball by Decisioneering, iDecide by Decisive tools and Monte Carlo by Primavera. The authors also figured out some shortcomings on risk analysis techniques. However, they believe that none of the RM tools is fully able to handle qualification of the impacts of the risks. As a result, the authors defined relationships between project goals, project activities, project risks and response strategies to help establishment a decision support instrument combined with an enterprise risk & response memory. It was proposed to integrate all aspects of risk management and set up of project performance models.

In their study Zou, Wang and Fang (2008) investigated infrastructure projects, in PPP (Public Private Partnership) terms, with an objective of developing a life cycle RM framework. After conducting an extensive literature overview, the authors linked their findings with case study methodologies. They studied on the projects in Australia and China, three PPP projects in total, and found out that assessing risks properly, ensuring value of money and protecting the stakeholder issues are vital for PPP infrastructure

projects. They only focused on proposing the framework, but not on testing it (Zou, Wang and Fang, 2008).

Lessard, and Miller (2001) prepared a study putting the nature of risks in engineering projects out with an idea of risks are multidimensional and therefore, they need to be classified to ensure an improved understanding for the reasons, results and impacts of them (Lessard and Miller, 2001).

With the idea of being large, uncertain and complex in many aspects, El-Dash, Abd-Raboh and El-Dars published their study in 2006. The authors have focused on major risks in the design phase of large construction projects. After collecting data, their identified risks were assessed by their severities. The assessment included qualitative analysis based on the expected probability – impact approach with the objective of defining and assessing the major potential risks that affect the design phase of large-scale projects in Egypt. As a result, the authors figured out that the following risks with the highest severity with respect to the design stage (El-Dash, Abd-Raboh and El-Dars, 2006):

- Lack of coordination among different disciplines
- Lack of Project Management Office
- Owner's frequent change orders
- Inappropriateness of available skills with the project
- Lack of quality control system

Klemetti (2006) prepared his study for the projects in Finland. She chose making interviews with 14 participants including representatives of the contractors and the subcontractors, as well as investor representatives from two different construction projects. Besides, she has conducted the literature overview to find out the related information. The author applied empirical study as a methodology to generate an understanding that the application area for RM is derived from the literature. In the lights of this thought, she formed a co-operative RM model for project networks. Finally, by help of the interviews she conducted, she was able to find the sources of the risks out for construction projects. She came out a conclusion, and it is a fact that, her the complexity of the networks introduces risks to the stakeholders (Klemetti, 2006).

It is for sure that to carry a successful study, the above explained literature would not be sufficient. That is why, an intense literature review for RM especially for the ones prepared for construction projects was carried. The following matrix gives a summary about them with key information of the authors and the one-sentence-aim of them. Besides, their techniques they used during the stage of obtaining information and the methodology they applied are indicated in the same matrix, as shown in Table 1. At the bottom of the matrix, explanatory information is given for abbreviated terms.

Table 1 – Summary of literature overview

<b>Author</b>	<b>Aim</b>	<b>Data</b>	<b>Methodology</b>
Alesin (2001)	Introduction of RM support system for Russian JV construction projects	HIST <sup>1</sup>	C&E <sup>2</sup>
Arndt, et al. (2005)	Creating complete outline for the nature of disability among construction workers	HIST <sup>1</sup> , COHORT <sup>4</sup>	STATS <sup>3</sup>
Ashley, et al. (1987)	Discussion on identification of political risks for international contractors	HIST <sup>1</sup>	-Discussion-
Baccarini and Archer (2001)	Application of a new risk ranking method – developed by Australian Department of Contract and Management Services	HIST <sup>1</sup>	PRR <sup>5</sup>
Baghdadi and Kishk (2015)	Considering Saudi Arabian aviation projects, identification and assessment of the risks	LO <sup>6</sup> , INT <sup>7</sup>	EJ <sup>8</sup>
Boateng, Chen and Ogunlana (2015)	Considering megaprojects, identification and assessment of the risks	LO <sup>6</sup> , HIST <sup>1</sup>	ANP <sup>9</sup>
Carr, et al. (2001)	Application of fuzzy approach	LO <sup>6</sup>	FUZZY <sup>10</sup>
Carr, et al. (2008)	Application of new software for international construction risk assessment	HIST <sup>1</sup> , EJ <sup>8</sup>	NRAS <sup>11</sup>
Choi, et al. (2004)	Considering infrastructure projects in Korea, discussion on RM	PG <sup>12</sup>	RAS <sup>13</sup>
Edwards, et al. (1998)	Discussion on literature about construction-related-risks	LO <sup>6</sup>	-Discussion-
El-Sayegh (2008)	Considering UAE construction projects, identification and assessment of the major risks	SRVY14	PRR <sup>15</sup>
Hastak, et al. (2000)	Considering international projects, application of new model RM	HIST <sup>1</sup> , EJ <sup>8</sup>	ICRAM-1 <sup>16</sup>

<b>Author</b>	<b>Aim</b>	<b>Data</b>	<b>Methodology</b>
Jaafari (2001)	Discussion on literature about construction-related-risks	EJ <sup>8</sup>	-Discussion-
Jannadi, et al. (2003)	Identifying risks for major construction activities	HIST <sup>1</sup>	RAM <sup>17</sup>
Javid and Seneviratne (2000)	Dealing with investment risk in airport parking infrastructure expansion	DOCSG <sup>18</sup>	MC <sup>19</sup>
Kangari, et al. (1995)	-Discussion- U.S. construction industry	SRVY <sup>14</sup>	QUAL <sup>20</sup>
Khalafallah and Khaled (2006)	Considering airport expansion projects, introduction of the development of a robust optimization model for planning site layouts	STAT <sup>3</sup> , HIST <sup>1</sup>	MOM <sup>21</sup>
Loosemore (2006)	Considering construction projects in Sydney, identification of the main project risks	SSINT <sup>22</sup> , DOCS <sup>23</sup>	EJ <sup>8</sup>
Lowery et al., (1998)	Considering the Denver International Airport construction, finding out the risk factors for injury	HIST <sup>1</sup>	PRM <sup>24</sup> , LRM <sup>25</sup>
Miller and Lessard (2001)	Considering large engineering projects, discussion on understanding and managing risks	LO <sup>6</sup>	QUAL <sup>20</sup>
Nasir, et al. (2003)	Risk analysis considering the upper and lower durations of the activities	LO <sup>6</sup> , EJ <sup>8</sup> , INT <sup>7</sup>	SA <sup>26</sup> , MC <sup>19</sup>
Nical and Wodynski (2015)	Considering Kraków Olympic Games 2022, introduction of a strategic approach to procurement issues	PRJD <sup>27</sup>	QUAL <sup>20</sup> , WI <sup>28</sup>
Nooter (2014)	Considering Dutch infrastructure projects, identification of the risk profiles	LO <sup>6</sup> , HIST <sup>1</sup>	QUAL <sup>20</sup>
Roelen, et al. (2000)	Considering Schiphol Airport, investigating feasibility of the development of a causal model	HIST <sup>1</sup>	DUTCH <sup>29</sup>
Sambasivan, et al. (2007)	Considering construction projects in Malaysia, identification of cause-effect relationships on delays	SRVY <sup>14</sup>	CORR <sup>31</sup>
Simister (1994)	Discussion on the project risk analysis in terms of its usage and benefits	SRVY <sup>14</sup>	-Discussion-
Taroun and Yang (2013)	Application of a new methodology called DST	LO <sup>6</sup> , HIST <sup>1</sup>	DST <sup>31</sup> , ER <sup>32</sup>

Author	Aim	Data	Methodology
Toth and Sebestyen (2015)	-BOOK- Developing an evaluation method and to provide a risk monitoring tool	LO <sup>6</sup>	HOLIST <sup>33</sup>
	<sup>1</sup> HIST: Historical Data	<sup>13</sup> RAS: Risk analysis software	<sup>23</sup> DOCS: Legal Documents
	<sup>2</sup> C&E: Cause-effect Technique	<sup>14</sup> SRVY: Questionnaires	<sup>24</sup> PRM: Poisson regression models
	<sup>3</sup> STATS: Statistics	<sup>15</sup> PRR: Project risk rating	<sup>25</sup> LRM: Logistic Regression Method
	<sup>4</sup> COHORT: Cohort Application	<sup>16</sup> ICRAM-1: Introduction of New Technique	<sup>26</sup> SA: Sensitivity Analysis
	<sup>5</sup> PRR: Project Risk Ranking	<sup>17</sup> RAM: Risk assessor mode	<sup>27</sup> PRJD: Project Data
	<sup>6</sup> LO: Literature Overview	<sup>18</sup> DOCSG: General Documents including contracts, regulations etc.	<sup>28</sup> WI: What-if Analysis
	<sup>7</sup> INT: Interview	<sup>19</sup> MC: Monte Carlo Analysis	<sup>29</sup> DUTCH: Introduction of Dutch Technique
	<sup>8</sup> EJ: Expert Judgment	<sup>20</sup> QUAL: Qualitative Methods	<sup>30</sup> CORR: Correlation Analysis
	<sup>9</sup> ANP: Analytical Network Process	<sup>21</sup> MOM: Multiobjective Optimization Model	<sup>31</sup> DST: Dempster-Shafer Theory of Evidence
	<sup>11</sup> NRAS: New Risk Assessment Software	<sup>22</sup> SSINT: Semi-structured Interview	<sup>32</sup> ER: Evidential Reasoning
	<sup>12</sup> PG: Professional Background		<sup>33</sup> HOLIST: Holistic Approach

The above literature overview study and its supplementary matrix summarize us the most relevant studies, books and articles, on RM in construction industry. Besides, the results of this stage show that there is not sufficient tool or technique which can easily be adopted and applied to manage the risks.

One of the relevant studies has been executed by Baghdadi and Kishk (2015). However, they were only interested in risks in Saudi Arabian ACPs, and obtained data by literature overview and interviews. They applied expert judgment as a tool of analyzing the risks.

On the other hand, Boateng, Chen and Ogunlana (2015) tried to identify and analyze the risks on large projects and obtained data from the literature and history. They chose only analytical hierarchy method to analyze their findings.

Considering international projects, Hastak, et al. (2000) used historical data and expert judgment to obtain information which were fed into a software developed by the same authors.

Javid and Seneviratne (2000) dealt with investment risk in airport parking infrastructure expansion, not considering the ACP, but considering only a part of it. They applied Monte Carlo Analysis to analyze gathered information by use of contract documents and regulations.

Apart from these, in this study applying qualitative methods is intended. A comprehensive study dealing with many aspects of ACPs, and not just the parking investment is intended. Besides, historical data will not be used, rather, semi-structured interviews and questionnaires will be used to obtain information, unlike Hasta, et al. (2000) and Boateng, Chen and Ogunlana (2015) who chose historical data for gathering information.

### **3. Risk Classification on ACPs**

Risk classification should always be taken into account as it is directly related to the goals of construction projects (Ojo and Odediran, 2015).

After warning the readers that different risk breakdown structures can be produced, PMBOK (2000) classifies the sources of the risks as external, organizational, technical, and project management. They are mostly related with the quality, performances and reliabilities, complexities and interfaces, technology, and requirements underlying technical risks. External risks consist of weather-related, customer-related, market-related, regulatory-related, and subcontractor-related risks. The risks due to prioritization, funding, resources, and project dependencies are listed in organizational risks. And finally, communication, controlling, planning, and estimating risks can be grouped under the project management risks.

According to Abdul Kadir et al., (2005), the most critical risks are material shortage at construction site, shortage of skilled labors, low management competency of subcontractors which can be considered as resource risks, late payments to contractors which can be analyzed under financial risks, variation orders which can be categorized under design and structural risks, delays in design approval which fits under time risks.

Decision makers on ACPs pay a great effort on identifying critical construction items. These are mostly related with resource risks including workforce and manpower, risks on project schedule, and the dynamic nature of the project. On the other hand, they need to concentrate on sociopolitical risks like changes in laws and regulations, environmental risks and nature events.

Risks for construction projects are classified into three groups by Abdou (1996): financial risks, design-related risks, and schedule-related risks. Perry and Hayes (1985) listed the risks possessed by contractors, consultants and clients. Environmental risks, industrial risks, client-related risks and project-related risks are the ones listed by Chapman (2001). On the other hand, Bu-Qammaz et al. (2009) approaches to risks in international construction projects under contractual risks, inter-country and country risks, project team and construction risks.

With regard to the information given in the previous sections, risks in ACPs can be summarized as follows:

1. Financial risks
  - 1.1. Market conditions and cost overruns
  - 1.2. Interest rate changes
  - 1.3. Currency fluctuations
  - 1.4. Late payments
  
2. Design and structural risks
  - 2.1. Poor/inadequate design
  - 2.2. Scope vagueness
  - 2.3. Failure to meet standards/quality problems
  - 2.4. Change in requirements
  - 2.5. Frequent scope changes
  
3. Sociopolitical risks
  - 3.1. Changes in laws and regulations
  - 3.2. Political instability
  - 3.3. Lack of political support
  - 3.4. Social grievances
  - 3.5. Terrorism & war
  - 3.6. Protectionism
  - 3.7. Taxation changes
  
4. Environmental risks/Natural events
  - 4.1. Adverse environmental effects
  - 4.2. Unfavorable weather conditions
  - 4.3. Seismic risk
  
5. Technological risks
  - 5.1. Poor technology management
  - 5.2. Lack of technology adaptation

6. Safety risks
  - 6.1. Failure to comply with health and safety laws
  - 6.2. Work accidents
  
7. Time risks
  - 7.1. Delay in obtaining site access
  - 7.2. Delay in design approvals
  - 7.3. Delays due to logistics/suppliers/contractors
  - 7.4. Delays due to resource inefficiencies
  - 7.5. Delays to obtain interim approvals
  - 7.6. Delays due to quality problems
  
8. Resource risks
  - 8.1. Turnover of key employee
  - 8.2. Low management competency of subcontractors
  - 8.3. Unavailability of material and equipment
  - 8.4. Shortage of skilled labors
  - 8.5. Lack of readily available utilities on site

**3.1. Financial risks:** Fluctuations in exchange rates are mostly unforeseen and may affect the health of the project, change in exchange rates can be counted as a financial risk (Hou, 2013). When international contractors, subcontractors or investors take part in airport construction projects, the financial risks tend to be higher compared to the non-international, in other words, local ones. Besides, the design and technique of the airport project may lead to procurement of the products from other countries. This brings associated financial risks with the risk of change in currency exchange rates. Han et al. (2004) believe that financial risks have subcategories such as currency fluctuations, changes in interest rates, and inflation rate which are expected to impact negatively the contractor's benefits.

**3.1.1. Market conditions and cost overruns:** According to Baloia and Price (2003), inadequate cost performance of construction projects is one of the biggest concerns from the contractors' and clients' points of view.

It is easy to make an inference that this is also valid for airport construction projects. The reported cases indicate that from the simplest to most complex projects, like transportation projects, have increasingly faced cost overruns.

Morris and Hough (1987) studied records of construction projects, which were funded by World Bank, and found out that 1,120 of 1,778, i.e. 63%, projects had experienced large cost overruns.

**3.1.2. Interest rate changes:** Contractor's profits are highly related to changes in interest rates. As the governments have power of control on interest rates, they may be assumed to be primary factor responsible for the risks related to interest rates. However, they usually pursue macroeconomic policies on interest rates which may also lead to unexpected fluctuations in it. That is why, contractors willing to participate in ACPs should take interest rates into their considerations. Even though macroeconomic policies are expected to minimize the probability of big changes in interest rates for stable economies, changes in interest rates are inevitable and they exposure risks on ACPs. On the other hand, a proper risk identification in developing economies implies that contractors and investors as stakeholders should evaluate the changes in interest and exchange rates (Thobani, 1999). Moreover, Wang, Dulaimi and Aguria (2004), figured out that risks on exchange rates and interest rates have a great impact on cost overruns.

**3.1.3. Currency fluctuations:** Another risk category for ACPs is currency fluctuations which can be portrayed as the negative result of changes in conversion limitations or currency where rates cannot be controlled by individual organizations (Kapila and Hendrickson, 2001). Considering the developing countries without a stable economic policy, political and economic developments may bring risk of currency fluctuations. Geczy et al. (1997) and Allayannis et al. (2001) believe that risks on currency fluctuations is the most important financial risk. Additionally, decision makers usually feel themselves in loss by the unwanted and

uncontrolled reasons like currency fluctuations. Another term, which is closely related with currency fluctuation, is currency crash defined by Frankel and Rose (1996) as “a large change of the nominal exchange rate which is a substantial increase in the rate of change of nominal depreciation.” Kapila and Hendrickson (2001) believe that currency fluctuations alter the profitability of trade. Besides, stability on currency rates enable contractors to ensure themselves to a certain degree against currency risk. In their study, Kapila and Hendrickson (2001) also proposed methods for contractors’ use to be used to manage their foreign exchange risk.

**3.1.4. Late payments:** This problem is very special to construction projects and needs to be studied in detail as it is born in every single project. There is no doubt that payment is needed to pay for materials, labor, plant, subcontractors, preliminaries and general overheads spent during the progress of the work (Odeyinka and Yusif, 1998). A probability of negative cash flow occurs if the flow of money is delayed during project duration. It may lead the contractors require urgent funding to handle the shortage of the cash. Easy to inference that late payments affect time, cost and quality (Ye and Abdul Rahman, 2010). On the contrary, some of the decision makers may believe that late payment can be acceptable (Cotter, 2005). In construction industry, late payment can be formidable since it will have a great impact on cash flows which are quite critical in especially for projects with comparatively long durations. Any kind of delays on payments will have impact on cash flows leading major impacts on the project (Ameer, 2006). “Once a payment problem starts to expand, it typically gets worse over time” says Gregory (2007) on late payments.

**3.2. Design and Structural risks:** These risks are the ones resulting from over-or underestimate of loads, like snow loads, wind loads, dead loads, etc. and/or selection of improper material by the designer for the airport to be constructed. Somehow, the design criteria such as seismic loads, snow and precipitation

loads, wind loads, snow loads may also differ by time which lead to considerably important risks (Designingbuildings.co.uk, 2015).

Risks of scope vagueness, failure to meet standards/quality problems, change in requirements, frequent scope changes are also evaluated in this category.

**3.2.1. Poor/inadequate design:** Unfortunately, construction practitioners have difficulties learning from their experiences, especially from their mistakes, particularly in terms of identification of design errors. However, poor and inadequate designs have been said to be the main cause of numerous accidents which may lead to partial or full collapses of completed permanent works which lead to financial losses and injuries of workers and/or members of the public (Lopez et al., 2010). The most recent example of this case is Construction Project of Hangzhou Tunnel in China. The collapse of Hangzhou Tunnel during construction phase caused 17 deaths. According to Ransom (2008), the main causes of this disaster were design errors and construction materials selected during construction process. Likewise, during the construction of Citicorp Building Project in New York, a structural change in design caused the building to be vulnerable to diagonal wind loads. Less than one year after the completion, one of the stakeholders found out the safety problem caused by inadequate design: The building was not safe as the structural connections were not designed to endure the wind loads. After a quick decision, the building has been repaired at a cost of \$8 million (Lopez et al., 2010). Studies show that design failures lead increase of 5 to 10% of the total investment budget in new projects (Bijen, 2003). Not only representing important costs, these failures also have the environmental burden associated with the construction rework (Lopez et al., 2010). The above-mentioned examples made this study to examine poor and inadequate design risks for airport construction projects as their impacts are considerably high.

**3.2.2. Scope vagueness:** Gibson and Hamilton (1994) define project scope as “the process by which projects are defined and prepared for execution”. A proper scope definition ensures success during the detailed design

and construction phases of a project. The contractors should know the scope for ACPs in detail in order to ensure success in their projects. If scope cannot be cleared in the beginning of the project, this will for sure lead failures. In this regard, scope vagueness should be analyzed for ACPs, as well.

To understand an airport construction project, identification of the work packages whether they are in or out of scope. It is a common and useful way to first find out the work packages which are out of scope to define the scope clearly. As long as the work packages are defined to be in or out of the scope, a project manager is to document it to enlighten his way during the project he manages. Once the scope is clearly defined for the project, the contractor or subcontractor is assumed to be ready to sign the contract. However, without a proper or well-defined scope, the next phases of the airport construction project may bring associated risks to take place. Since the well-defined scope gives the main idea of the project to the managers, lack of it is likely to introduce new risks to the airport construction projects.

**3.2.3. Failure to meet standards/quality problems:** Kamara and Anumba (2000) states that initial connections to the industry is ensured by client requirements which impose the expectations and/or constraints of the client on the project functionality and quality (Gilb, 2005; Zielczynski 2008; Robertson and Robertson, 2005). However, design professionals' inducement usually varies from client's intent to the proposed facility (Friedlander, 1998). To ensure being successful on the project, client's requirements should be fulfilled (Chan et al., 2002).

**3.2.4. Change in requirements:** Related to above last risk subcategory, requirements of the client are the key factor for the project success. This brings the fact that if the client's requirements change by time, i.e. during construction phase, contractor will face difficulties on satisfying new requirements as his previous works were executed in terms of client's previous requirements. Mostly, clients deny making additional

payments and giving additional time frame to make contractor fulfill new requirements. This brings new risks on already risky endeavor.

**3.2.5. Frequent scope changes:** Scope change can be defined as any change to the project scope and requires new adjustments to the project budget and/or schedule (PMBOK, 2000). If a change in the scope occurs, a change request to be prepared by the contractor for client's approval. Change requests should have variance analysis which aims to figure out how the original scope has been changed prior to submitting clients' approval. This is why, if scope changes occur frequently, large numbers of man-hour losses which lead financial losses and delays can be faced.

**3.3. Sociopolitical risks:** Compared to the past, sociopolitical pressures and risks have more impact on construction. Political pressures have great impact on public and private sector projects. Besides, the ventures have larger amount of inputs through non-governmental organizations that are engaged during design, project implementation and construction. As mentioned in previous chapters, a great stakeholder group leads complications on an already complex mechanism. Sociopolitical effects also come from the Not in My Back Yard (NIMBY) Syndrome which was defined as "an intense, sometimes emotional, and often adamant local opposition to siting proposals that residents believe will result in adverse impacts" by Kraft and Clary (1991). Davis and Lester (1988) believes that NIMBY reaction became common as the benefits and costs distributed make opposition to local residents.

The sociopolitical risks also consist, as the name implies, political concerns. Since the airports are mostly invested by the governments, any change in the ruler may lead the airport construction project to be slower, or even stopped. Besides, security problems, being exposure to legal action, consumer protests, lack of end-user acceptance, reputational damage can be listed in social risks in airport construction projects.

**3.3.1. Changes in laws and regulations:** Even changes in regulations and laws are seemed to be least critical risk subcategory (Sweis et al., 2008)

for construction projects in Jordan, it is good to see the analysis results for ACPs as they are very sensitive with and related to laws and regulations.

**3.3.2. Political instability:** Political instability is said to may or may not affect construction industry. However, it might have a slight impact to the construction industry or a construction-related-sectors, which is likely affect the airports being constructed. This is why, to make a risk assessment from an ACP point of view, making identification ACP is probably to be influenced by its environment is important (Hastak and Shaked, 2000). On the other hand, most of the macro sociopolitical (MSP) models define the political instability factor as a combination of various economic, ideological and social forces (Knudsen, 1974) (Haner and Ewing, 1985) (Ting, 1988). In this approach, it is assumed that political events influence the economic development and business conditions in the country where the project is to be executed. Therefore, sociopolitical environment may result political instability which is likely to cause drastic changes in the business environment.

**3.3.3. Lack of political support:** Considering lack of political support, the term of “comfort letter” should first be described. This letter is a support letter prepared by the governments. Without any doubt that comfort letters do not ensure legal rights by the governments. Besides, in case of any change in governmental level, there is a possibility that the new government may not want to continue with the terms of previously issued comfort letters (Digital.milbank.com, 2014). Neerdel (2007) defines political acceptance as a certain policy having an active support by the political rulers. Legislatures, government entities, elected representatives can be given as examples for above mentioned political ruler which can also be stated as stakeholders for ACPs.

**3.3.4. Social grievances:** Nerdel’s (2007) following explanations will describe the importance of social grievances on ACPs: Public acceptance infers that a specific approach or a specific solid measure is

unmistakably or implicitly upheld by individuals from the public who might be influenced, positively or contrarily, by its execution. Some populations thusly will be recognized by the arrangement or measure being referred to. Note specifically that a neighborhood populace (community) should regularly be recognized from a national populace at large, and that the level of acceptance that can be seen in each kind of population may conceivably rely upon various variables or different highlights of the situation. Regardless of whether public acceptance exists or not can be evaluated with differing degrees of accuracy, through means extending from formal referenda, properly-conducted questionnaires or focus groups indications to media discussions and educated decisions from individuals acquainted with what is talked about among individuals from the general population. It ought to be noticed that "passive" acceptance i.e. not dynamic resistance might be enough to settle on decisions on setting up a program on geologic disposal, however could not be adequate for the long decision-making process. An effective relationship of pertinent partners in the whole decision-making procedure ought to be reflected in the robustness and sustainability of latest decisions.

**3.3.5. Terrorism & war:** Terrorism and war is being discussed under same subtitle as the impacts of them are alike and they need to be taken into consideration during execution stage of an ACP. This risk simply means attacks on construction site because of terrorism and/or war. Mostly, the risk will be shared between contractors, investors and insurance companies. However, the insurance sector was deeply affected because of September 11<sup>th</sup> attacks and governments stepped in to help in accepting some of the risk. This brings another decision-making issue how the terrorism and war risk will be allocated (Kosnick, 2005).

**3.3.6. Protectionism:** This term, protectionism, is used in economics, implying a conservative approach to locally produced products. This economic policy harnesses the international trade by a couple of

methods such as customs duties on imported products and goods and limiting quotas (Wikipedia, 2016). This policy’s aim is to protect domestic goods and products against the ones from other countries and by this way to strengthen the subsistence and powerfulness of local industries. However, it sometimes results to high prices of goods and products locally available in the market and may be harmful for competitiveness (Batisse and Poncet, 2004).

Kant (1976) alleges that “protectionism results in deadweight loss; this loss to overall welfare gives no-one any benefit, unlike in a free market where there is no such total loss”. Figure 4 indicates protectionist measures between years 2008 and 2013.



Figure 4 – Protectionist measures between years 2008 and 2013

(<http://www.globaltradealert.org/>)

**3.3.7. Taxation changes:** Bing et al. (2005) defines risk of tax regulation as a business issue, and adds that it should certainly be assigned to the private contractor. He also after allocating eleven risk factors, in which tax regulation changes also appear to the private sectors, reports that this risk is shared with public sector. It is not surprising that some of the participants allocated tax regulation risks to be shared between

private and public. Besides, tax regulation changes are located in macro level risk category. (Bing et al., 2005)

**3.4. Environmental risks/Natural events:** When the environmental analysis is incomplete, the airports may be located at improper places which are harmful to the environment. In Istanbul New Airport Project, it is told that the location of the construction site is in the flyway of around 600,000 migratory birds which migrates from Africa to Europe. Moreover, these birds used to use that area as recreation area. Of course, this is not a parameter to be concerned by the contractor, but by the investor. However, the contractor and the subcontractors may face intense protests during construction stages which may slow down, or even stop the project.

**3.4.1. Adverse environmental effects:** Inevitably, like other construction projects, ACPs may cause environmental concerns, which impact construction, including hazardous waste, air pollution, water pollution, dust and contamination of soil, as well as noise. These burdens increase the risks in ACPs, and they should be properly identified and managed. Most of the time, environmental harmful effects of construction projects are tried to be prevented by regulations and laws. There is no excuse to ignore such regulations which may lead putting the project, client, contractor and decision makers in jeopardy (Muir, 2005).

**3.4.2. Unfavorable weather conditions:** In their study, Bing et al. (2005) classify the unfavorable weather conditions under macro level risks, external to the project itself, by risk category named natural. According to them, unfavorable weather conditions are named as natural risks and they are crucial during construction stage as should be borned by the contractors.

**3.4.3. Seismic risk:** It is good the express that seismic factors are taken into consideration by the design engineers like other nature events like wind and rain/snow loads (Housner, 1952) (Gzovsky, 1962) (Blume, 1965) (Newmark, 1967).

During execution phase of ACPs, like all other construction projects, earthquakes exposure risks on the partially completed works and it is critical how they can handle that seismic loads within the design magnitude. Not only the partially completed permanent works, but also the temporary facilities are subject to seismic risks (Mustafa and Al-Bahar, 1991). That is why, seismic risks for ACPs becomes a risk category which must be analyzed.

**3.5. Technological risks:** The development in technology brings the ease of application in all kind of industries including construction. It is essential for the contractors, subcontractors and the consultants to use technology to entrench the construction stage of the ACP is in proper schedule, product quality and human and work safety. If the contractors, subcontractors and consultants fail implementing technological development to the airport construction project, this will unfortunately lead to loss of money, and reputation in the industry.

**3.5.1. Poor technology management:** Technology management is important in terms of producing goods and improving efficiencies. The decision makers in ACPs should be able to identify the needs of the projects and select the most proper technological equipment. Besides, they must be good at understanding the needs of the technology to be implemented, for example the capacity of the tower and mobile cranes and the allocated space around them should be clearly identified prior to using a crane. No doubt that a failure in technology management causes delays in project schedules, losses in earnings and reputation.

**3.5.2. Lack of technology adaptation:** Technology adaptation can be studied with transfer of technology. Technology transfer can be done from one sector to another, as well as from one country to another. As the name implies, technology transfer involves a source which already uses the technology needed and a target which needs to have the technology to be able to produce goods or improve efficiencies. For technology adaptation, the level of need and acceptance of the target is vital for

transferred technology. For this reason, a detailed market search and identification of requirements and specifications are important. Decision makers and contractors must be able to adapt transferred technology to produce goods and improve efficiencies.

**3.6. Safety risks:** This type of risks is mostly related with the workers and the staff who are working on site during the project. The contractor or subcontractor is responsible to take the necessary precautions against falls from a height, falling and moving objects, collapse, electricity and handling loads to prevent unwanted accidents in construction site since such accidents may lead to life losses, monetary losses and reputational losses.

**3.6.1. Failure to comply with health and safety laws:** Even though there are international laws and regulations in the world, every country applies their own health and safety laws for construction projects, as well as for ACPs. Eventually, prospective contractors who are interested in constructing airports should examine the local health and safety rules of the country where the airport is to be constructed. Not only for the countries, but also the unions of the countries may impose health and safety regulations. For instance, a new Strategic Framework for the countries in European Union has been issued by European Commission (EC). By this framework, it was aimed to protect more than 200 million workers against work-related diseases and accidents (Ec.europa.eu, 2016).

This framework has three objectives:

- “to improve implementation of existing health and safety rules, in particular by enhancing the capacity of micro and small enterprises to put in place effective and efficient risk prevention strategies
- to improve the prevention of work-related diseases by tackling new and emerging risks without neglecting existing risks
- to take account of the ageing of the EU's workforce.”

This framework has seven strategic challenges

- “Further consolidating national health and safety strategies through, for example, policy coordination and mutual learning.
- Providing practical support to small and micro enterprises to help them to better comply with health and safety rules. Businesses would benefit from technical assistance and practical tools, such as the Online Interactive Risk Assessment (OiRA), a web platform providing sectorial risk assessment tools.
- Improving enforcement by Member States for example by evaluating the performance of national labor inspectorates.
- Simplifying existing legislation where appropriate to eliminate unnecessary administrative burdens, while preserving a high level of protection for workers’ health and safety.
- Addressing the ageing of the European workforce and improving prevention of work-related diseases to tackle existing and new risks such as nanomaterial, green technology and biotechnologies.
- Improving statistical data collection to have better evidence and developing monitoring tools.
- Reinforcing coordination with international organizations (such as the International Labor Organization (ILO), the World Health Organization (WHO) and the Organization for Economic Co-operation and Development (OECD) and partners to contribute to reducing work accidents and occupational diseases and to improving working conditions worldwide.”

**3.6.2. Work accidents:** Construction sector is one of the most pestilential sectors in the world. There are more occupational fatalities in construction sector than any other sector. In the US, rate of fatal occupational injury among construction workers was approximately three times higher than all remaining workers. Among construction

workers, falls are one of the most common causes of fatal and non-fatal injuries. Risk of occupational injuries can be reduced by usage of proper safety equipment such as harnesses and guardrails, and procedures such as securing ladders and inspecting scaffolding.

**3.7. Time risks:** Risks of delays in project schedule are the critical risks for ACPs as they lead to financial losses and reputational damages. Because of this reason, decision makers and project managers should pay attention for time related risks to prevent their companies against such losses. The followings are some subcriteria for time related risks.

**3.7.1. Delay in obtaining site access:** Contractors should get site access within the specified time frame. The common time frame for site access is 30 days after contract signature. Contractors should get permission from local and national authorities such as project owners, landlords etc. in the most suitable time frame for themselves since early permissions may put the contractors to unprepared situation and late permissions may put them late as the project duration usually starts with contract signature.

**3.7.2. Delay in design approvals:** Not only for “Design and Build” projects, but also for build-only projects, the contractors need to study the design of the project. Most of the time, the contractors are asked to make detailed design for the structural, architectural and MEP solutions. If the contractor prepares the design documents late, then the approvals eventually come late, either.

**3.7.3. Delays due to logistics/suppliers/contractors:** Another most common risk on ACPs, like other construction projects, is due to delays in logistics, suppliers and subcontractors. Project managers should take necessary precautions and choose the most capable, experienced suppliers, service providers and subcontractors to prevent themselves against such kind of delays.

**3.7.4. Delays due to resource inefficiencies:** Resource inefficiencies are one of the most critical risk for construction projects. Efficient resource allocation is vital to make project and project management successful and contrarily, inefficient resource allocations are like to result delays. Listing this risk subcategory here aims to see the importance of this subcategory for ACPs according to the experts.

**3.7.5. Delays to obtain interim approvals for work progress:** Like other construction projects, the ACPs are sensitive with the progress approvals which are supposed to be done by consultants or by clients. Interim approvals will guide contractors to continue their work, and get paid accordingly.

**3.7.6. Delays due to quality problems:** Due to various reasons like improper workmanship or material used, contractors may face quality problems which are not approved by the consultants or clients. This may lead to repeat the activities and delays in schedule.

**3.8. Resource risks:** Resource risks are the ones which are related with staff, equipment, and material.

**3.8.1. Turnover of key employee:** Most of the contractors choose to recruit staff after they get awarded for ACPs. Usually, the engineers who worked for ACP during tender stage are preferred since they have the largest network and information for the project. In case key employee wants to quit his job because of any reason, contractor is likely to face losing connections and information gathered during tender stage, even if the key employee shares all information, he has with the other team members. Because of this reason, the contractors should choose a way to expand the key employee team by providing them a job security.

**3.8.2. Low management competency of subcontractors:** Inevitably, contractors commonly work with subcontractors which are experienced and specialized in their work areas. Working with various

subcontractors bring a problem of management among them. From time to time, different subcontractors work in the same area and it may cause some conflicts in their works. Project managers should be able to organize and manage them in order to prevent such conflicts and related delays.

**3.8.3. Unavailability of material and equipment:** Unavailability of enough material was identified as the most critical risk in construction sector in Nigeria (Olomolaiye et al., 1987), Iran (Zakeri et al., 1996) and in Indonesia (Kaming et al., 1998) as it imposes delays. In their study, scholars Abdul Kadir et al. (2005) found lack of material as the most important risk factor in construction projects as 64% of their focus group ranked it as “strongly important”, as given in Table 2.

Table 2 – An informative section of the result table for Malaysian residential projects (Abdul Kadir et al., 2005)

Project related factors	Degree of importance quoted by 100 respondents					Total respond	Importance index	Rank
	1 – Strongly important	2 – Important	3 – Neutral	4 – Not important	5 – Strongly not important			
Material shortage at project site	64	28	7	0	2	100	0.912	1
Non-payment (financial problem) to suppliers causing the stoppage of material delivery to site	51	35	9	5	0	100	0.870	2
Change order by consultants causing project delay	43	40	14	3	0	100	0.848	3
Late issuance of construction drawing by consultants	38	45	16	1	0	100	0.844	4
Incapability of contractor's site management to organise site activities	40	43	14	2	1	100	0.840	5
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Reluctance of consultant's site staff to work extra days on sunday and public holiday	10	20	38	24	8	100	0.598	50

As a result of shortage in material and equipment, workers on site may become idle while waiting for the necessary materials and equipment. Shortage is mostly due to materials such as rebars, formwork and concrete, as well as equipment such as bending machines, vibrators, hand tools and also cranes which directly impacts the work schedule in negative way. This is why, project managers should properly plan to ensure that the critical equipment and materials are accessible at construction area when needed. On the other hand, if critical materials and equipment delivered to construction site very earlier than needed, double handling which leads loss of man-hours may take place.

**3.8.4. Shortage of skilled labors:** According to Abdul Kadir et al., (2005), one of the most critical risks is shortage of skilled labors.

**3.8.5. Lack of readily available utilities on site:** The project managers and decision makers should make the utilities such as working yards and temporary sanitary works available on site. This aims to ensure preventing the idle time of site personnel which may lead time losses.

Above mentioned risk categories and subcategories show that the intangibility character of the risk factors make them not to be clearly separated from each other. For example, while some of the decision makers accept protectionism as one of the financial risk factors, the others protect it as under sociopolitical risk. This is because of the difference in understanding risk and its effects on ACPs.

## **4. Methodology**

In this study, several methods have been applied for gathering information and assessing them. Details of the implemented methods are explained in the coming chapters. Semi-structured interviews have been conducted to gather more information on risks in ACPs and consequently analytical network process has been applied to learn about the most important risk factors in ACPs.

### **4.1. Consideration of Ethics during the Study**

To ensure the ethical considerations to take place, application forms have been submitted to Ethics Committee to have their approval prior to starting this study. In these application forms, it was promised that the semi-structured interviews and the questionnaires will be conducted on voluntary basis, which allows one to reject participation and contribution to the study. During this research study, the aim is to execute interviews not with the minors, but with the adults. The strategy of the study is far from being stressful, and the subject and the aim of this study have been clearly told to the participants in order to get their confirmation to participate in these semi structured interviews and questionnaires. There has been no method which would threaten the physical and psychological health of the participants. Manipulation techniques and procedures have not been applied. All of the participants have had the right to leave the interview or questionnaire in any time they wanted. The collected data from semi-structured interviews have only been used to contribute to this study and have not been shared with the other parties and participants. The credentials of the participants will be kept confidential and they will not be shared with third parties without their permissions. After completion of the study, the participants will be informed about the results of this study.

### **4.2. Semi-structured Interviews**

Similar to other studies, this study also has several phases, beginning with the topic selection. Obtaining information about the risks appears to be at the very early stages in RM. Since the identification of the risks is important to take required precautions accordingly, this thesis study will aim risk identification and prioritization of the risks. Providing RM perspective to the decision makers is very important, since it will assist them in making their decisions within the process, accordingly.

As it implies, “risks” are because of the forthcoming events which have not happened, yet, which means the probability of their occurrences can only be estimated. When estimations take place in a study, it may impose subjective estimating environment. In this step of this study, experts are asked to make subjective estimates on risks based on their experiences in ACPs.

Prior to identifying the risks, it is essential to obtain relevant information. There exist several techniques for gathering information. Interviewing, questionnaires, brainstorming, expert judgment, probability distributions, SWOT analysis, diagramming techniques, assumption analysis, checklist analysis and Delphi technique are some of the techniques to obtain information (PMBOK, 2000).

The aim of conducting interviews is to understand other individuals’ stories because they are of worth it (Seidman, 2006). Interviewing is a good tool to get information on risks, as the experience of the individuals whose professional backgrounds are expected to reflect the airport-construction-project-related risks. However, with the aim of keeping the interviews in the way of gathering accurate and proper answers, semi-structured interviewing technique needs to be applied as it allows one to learn what is wanted to be founded out by its flowing characteristics.

As a verbal tool, semi-structured interviews, is a powerful method to obtain information for a particular topic. They are suitable to work with focus groups, and for clearly defined objectives aiming to obtain information on them (Laforest, 2009). By this method, the researcher can easily evaluate the answers given by the participants by examining his non-verbal gestures (Gordon, 1975). Besides, it ensures that the participant will be alone, without any assistance from others, to respond (Bailey, 1987). Mainly, this method will answer the following questions:

- What do experts know about risks and risk management?
- What is their approach?

Semi-structured interviews have several advantages and two of them can be listed as below:

1. They are suitable to examine the opinions and perceptions of the participants on a complicated subject, such as risks, by letting researcher to ask for more detailed information on the subject.
2. The semi-structured interviews can be applied for a group of participants from various work groups to get more information from their personal, educational and the professional backgrounds. (Louise Barriball and While, 1994).

The questions are prepared to be responsive according to the answers given by the opponents. That is, the upcoming questions asked to the participants may change according to his previous answers. Like other verbal tools, a focus group has to be determined to conduct the interview (Laforest, 2009). In this study, a focus group of eight people consisting of project directors, department managers, experts, and consultants and major subcontractors who have been involved in airport construction projects has been identified. The questionnaire prepared for this method can be found in Appendix Section.

Knowing the fact that the profile of the focus group chosen would affect the outcome of the semi-structured interviews, a detailed study was conducted and the most appropriate participants were selected to be interviewed. Majority of the focus group include project and department managers. Besides, consultants and major subcontractors were reached to ensure diversity of the outcomes. Numbers and roles of the participants can be outlined as given in the Figure 5:

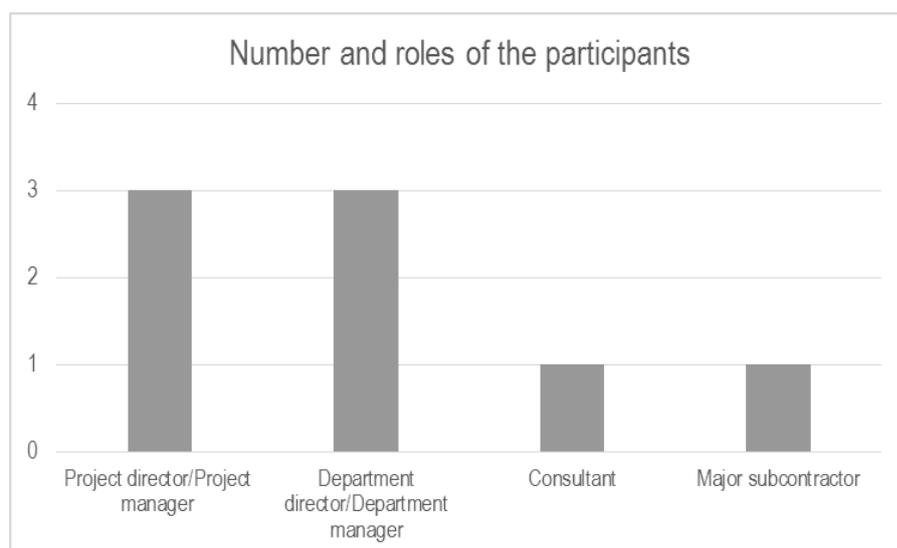


Figure 5 – Number and roles of the participants

Albert Einstein was very assertive while saying that the only source of knowledge is experience. This makes not only the role, but also the experience level of the participants matter for semi-structured interviews. This made focusing on the group of participants with higher level of experience compared to the others essential. Figure 6 illustrates the experience level of the participants in general, and in ACPs, and it shows that majority of the focus group is experienced in construction industry for more than eleven years. Besides, six participants out of eight have more than six years of experience in ACPs.

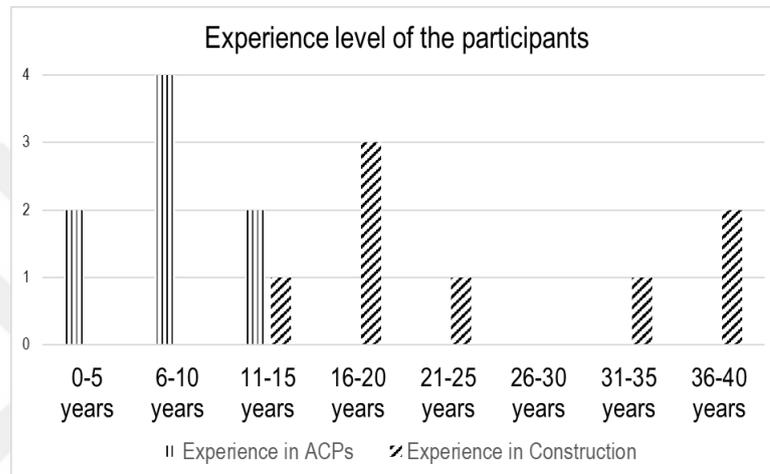


Figure 6 – Experience level of the participants in focus group

Some important information of the participants is summarized in Table 3. This table has the roles of the participants, their level of experience and their current job descriptions.

Table 3 – Roles, level of experience, current job descriptions of the participants

<b>Role</b>	<b>Experience level</b>	<b>Job description</b>
Risk Department Manager	16 years of total experience with 3 years in ACPs. Has been working for 4 ACPs (3 of them ongoing) in 3 different regions including Africa, Asia including Middle East, and Europe.	Analyzing financial risks for his company
Project Manager	30 years of total experience with 7 years in ACPs. Used to be certified. Has been working for 6 ACPs (4 of them ongoing) in 3 different regions including Africa, Asia including Middle East, and Europe.	Project management, coordination of subcontractors for his company
Project Director	36 years of total experience with 12 years in ACPs. Has been working for 7 APCs (4 of them ongoing) in 3 different regions including Africa, Asia including Middle East, and Europe.	Project Management, decision maker for his company
Consultant	40 years of total experience with 9 years in ACPs. Has been working for 5 ACPs (2 of them ongoing) in 3 different regions including Africa, Asia including Middle East, and Europe.	Owner of the company, advisor
Project Manager	25 years of total experience with 6 years in ACPs. Worked for 2 ACPs in 2 different regions including Africa and Asia including Middle East.	Project Manager, decision maker for his company
Department Manager	11 years of total experience with 3 years in ACPs. Worked for 2 ACPs in 2 different regions including Africa and Asia including Middle East	Mechanical Works Department Manager for his company
Department Director	16 years of total experience with 9 years in ACPs. Has been working for 3 ACPs (2 of them ongoing) in 2 different regions including Africa and Europe.	HSE Department Director, responsible for environmental, social applications of the all employees in his company
Major subcontractor	17 years of total experience with 6 years in ACPs. Has been working for 2 ACPs (2 of them ongoing) in 2 different regions including Asia including Middle East and Europe.	Representative and project manager of a roof cladding works subcontractor

It is good to note that focus group reached a common understanding that working for government or for contractor makes them approaching the risk in different ways. In this study, risks in ACPs have been assessed from the contractors' points of view.

All of the participants in focus group agree that risk identification is required and essential, and a detailed risk identification should be applied for each ACP. This result implies that a detailed risk management study is needed for ACPs as they are strategic projects.

Even though some of the participants think that compared to the early years in ACPs, their understanding in risk identification methods did not change, it is a clear outcome of semi-structured interviews that risk changes as the time passes. Getting experienced allows investigating minor risks which may create high impact if not dealt with. Furthermore, considering duration, relationships between different disciplines and the integration of the different electronic systems, the understanding of the risk is being changed by time and technological developments.

The major outcomes of the semi-structured interviews can be summarized as follows:

- A result of the interviews is that the contractors nowadays are after reducing the risks during ACPs, and providing sustainable projects.
- Participants agree on that ACPs have a characteristic terminology which is special for such projects.
- Participants came to a mutual understanding that the risks in ACPs are initially construction-based risks. However, the complicated designs of the airports make project managers and other stakeholders investigate risks in ACPs in terms of obstacles, noise pollution, etc.
- Participants believe that there might occur uncommon risks for airport operators, but not for contractors, for example, if the airport is designed to be on the flyway of migratory birds as they can be risky for the aircrafts during airport operations.
- Another risky item which participants take into consideration is the foreign object damage (FOD) risk which becomes an important risk item for the airport expansion projects.
- Participants agree that their understanding of risk will not change in the future. However, investors believe that, as the guarantee mechanisms evolve, the change in risk understanding is inevitable. For instance, the passenger rate is the most important parameter to analyze risk according to the investors.

- The participants think that risks in tender stage have more uncertain items compared to the construction stage. In the pretender stage, there are various assumptions related to the project which are realized in a good or bad way during the construction stage. Sometimes, decision makers should accept that they were wrong in their assumptions in tender stage. They believe that risks related with the construction stage should also be considered during tender stage. Because, it is expected that the forecasted risks are realized during execution stage.

Moreover, during pretender stage, there are risks related to the contract documents and the quantities which lead to financial and contractual fluctuations. During post tender stage, the risks which could not have been identified during earlier stages may come up and make contractors deal with mitigation of these unforeseen risks.

Upon a question whether they have ever decided not to attend an ACP tender considering its risks, the majority of the participants said yes. However, the reasons behind these decisions differ from one to another. While some of them decided not to attend for a tender because of high construction costs, the others decided the same because of political risks in the country where ACP is located. Risk of terrorism and war, as well as local currency fluctuations, made decision makers not to attend the ACP tenders in certain countries.

- A common understanding of the participants is that risk changes by time. During pre-tender stage, an item may be seen as risky, however, it may change its characteristics when we come to the construction period. The opposite of this situation is also valid. Well-prepared risk registers and tracking them are vital for ACPs. Participants are aware of the fact that there are softwares in the market which allow decision makers to find out the uncertainties during their dynamic organization. Even risks change by time, a proper risk management plan allows generating responses for unforeseen economic changes like changes in fuel prices, construction costs etc.
- As an outcome of the semi-structured interviews, participants believe that the work schedule prepared during the pretender stage should be investigated and studied well, and durations and procurement issues should be in parallel with each other. However, during the construction stage, contractors may have to install tailored instruments and the products as needs of every ACPs change.

- When asked to define risks in ACPs, the participants gave responses due to their positions. Some of them stated that risk differs with the type of involvement of the parties in the project. An investor may face with the risks of traffic, planning and idosecretic risks, and reputational risks come across as well as with the bankruptcy risk for the aviation companies. As an operator, one needs to apply sustainable risk planning techniques. Besides, organizational risks can also be counted in the risks of ACPs. From the contractors' point of view, risks are inevitable. Risk is the combination of the occurrence of the effects of a risky item.

Risk management during risk identification period is the process in which contractors deal with identification and the mitigation of the risks which are not directly in the project. Contractors need to define every single risk and their response plans, accordingly. For instance, power generation should be supplied not from one single source. There should be substitute generators, as well. If the contractor will also operate the facility after the construction is over, the risk of passenger traffic is also important and should also be taken into consideration. Definition of risk differs from region to region. Considering, for instance, mechanical systems like the ventilation system, the risk changes in hot and cold climates which affects risk registers.

Other major outcomes of the semi-structured interviews can be summarized as followings:

- The response of Health and Safety, Environment (HSE) Department Director for defining risks was related with HSE risks and warned that a deadly work accident may cause the follows:
  - Time losses due to stopping the work
  - Psychological results for workers and the management
  - Negative effects on productivity
  - Unforeseen costs
  - Loss of reputation
  - Direct losses due to indemnities
  - Long court periods up to 10 years
- Participants believe that compared to other projects, risks in ACPs differ. Different from the infrastructure projects like dam and highway projects, ACPs

are special since, they involve technology more than any other construction type. The technology of the airports, like aircraft traffic management system changes every day. Contractors need to catch up with the latest trend in the aviation industry and it is difficult to recover faults in ACPs. However, other superstructure projects are generally ordinary and done by traditional methods.

- For ACPs, new trends are to be followed properly and the latest technological instruments should be implemented to the project. If it is an airport expansion project, the construction stage in an operating airport is more difficult as the safety of aircrafts should be taken into consideration. On the other hand, there are many technical parameters in ACPs. Technical wares, softwares, and facilities are used to minimize these risks.
- Moreover, participants warn contractors that they will be responsible for about 10 years for the construction quality.
- Participants think that contractual risks are relatively important risks compared to the others.
- Risks are very different from one region to another. For the countries in which the application of international regulations and technology are powerful, then the risks to be faced are lower.

On the other hand, risk considerations change from region to region. For example, taking care of hygiene and having local labor obey regulations can be counted as risk factors in Africa, but not in Europe or US. As another example, exchange rates are more stable in Europe than in other regions where they fluctuate frequently.

Participants raised another interesting example to how risks change from region to region: There is no tsunami risk in Cairo, however, there is a tsunami risk for Maldives.

Big risks are always expected for every ACPs in the world. They are mostly price-related risks, or strikes. Clear regulations help in eliminating the risks.

- Participants believe that the thriving economies are always subjected to have larger risks compared to more stabilized ones.

- Participants raise the risk of climate conditions which is likely to create different risk categories. For example, temperatures like -40°C and +50°C may slow down the works.
- Governmental sustainability is told by the participants to be one of the most critical risks among others. One of the participants declared that during the military coup in Egypt in 2013, they lost most of their labors and they were required to replace the lost workers in the shortest time.

Participants mostly think that historical data for the similar projects should be analyzed for the upcoming ACPs. For this purpose, every kind of risk is included in a risk matrix, which is also called as risk register. The matrix allows managers to create a risk map. In this risk map, the impact and the chance of occurrences are noted down and, accordingly, a risk response plan is generated. The following sample in Table 4, which was prepared for Sabiha Gökçen International Airport Project, the components of risk register are shown.

Table 4 – A risk register sample (abbreviations in Resp. Column stand for initials of the responsables)

SGIA INTERNATIONAL AIRPORT RISK MANAGEMENT PLAN RISK ASSESSMENT REGISTER							
8.0 Construction							
No	Risk	Cause	Occurrence Likelihood	Impact on Project	Risk Mitigation Measures	Resp.	Date
8.1	Failure to manage, non-performing subcontractors.	Management systems are not in place or are not used	M	H	1. Ensure procedures are put into place to Manage subcontractors. 2. Train all staff in the implementation of the procedures. 3. Carry out internal and external audits to ensure that procedures are being implemented.	DR HC HC	30.03.08 Ongoing Ongoing
8.2	Failure to establish a robust permit to work system results in stoppage of works until approvals are obtained.	Coordination does not take place with HEAS and for other local authorities regarding the procedures to commence the works	L	M	1. Prior to the commencement of any works that opens up new work areas or the use of common use access roads a permit to work system will be agreed with HEAS. 2. The PTW systems will be subject to regular audit.	OC HC	7.03.08 Ongoing
8.3	Existing services are damaged due to failure to identify. This results in costly repairs and delays to the works.	1. Inadequate surveys or lack of available drawings to identify existing services. 2. Failure to implement site procedures	M L	M M	1. Training to be given to all Construction staff in correct procedures to identify existing services. 2. Use of procedures will be evaluated by audits.	HC HC	Ongoing Ongoing
8.4	Poor logistic management results in delays to the works.	Logistics and not considered in the planning and construction stage.	L	M	Logistics are to be written in to the Contractors weekly progress reports and become part of the Method Statements.	Construction	Ongoing

They also agree that risk identification process is mostly related with cost and time for ACPs. In this regard, believing that even they are not commonly used, simulation techniques need to be applied for financial risks as they are good to use over time. As the one starts to simulate the model, it shows the impacts by time. For instance, a risk

of fire is very hazardous in the ACPs in progress. In every project, even the impact of this risk is low at its early stages, it shows an ascending trend by time. Likely, the impact of risk of falling height changes as the work progresses.

In addition, participants believe that other risk categories like key personnel risks should also be taken into consideration. They think that the management team should take necessary precautions in case one or more key personnel quit their jobs. Besides, backup of the data storage is generated against cyber-attacks in terms of resource risks.

An outcome of semi-structured interviews is that decision makers confess that they generally choose the way of solving and mitigating risks as soon as they occur. Without any doubt, a successful monitoring of the risks helps reducing impacts of the risks.

#### Spider web diagrams / Radar plots:

Spider web diagrams are graphical techniques for showing multivariate information as a two-dimensional diagram of at least three quantitative factors represented on axes beginning from the same point. The point of the axes and relative position is regularly uninformative (Wikipedia, 2016).

The radar chart is a graph that comprises of a grouping of equi-angular spokes, called radii; each spoke showing one of the factors. The information length of a spoke corresponds to the size of the variable for the information directly relative toward the most extreme greatness of the variable over all information focuses. A line is drawn interfacing the information esteems for each spoke. This gives the plot a star-like appearance and the starting point of one of the mainstream names for this plot. The star plot can be utilized to answer the accompanying inquiries (Itl.nist.gov, 2016).

- a. What perceptions are similar to each other, i.e., are there clusters of perceptions? (Radar plots are utilized to analyze the relative qualities for a solitary data point and to find similar focuses or disparate ones.
- b. Are there anomalies?

Radar plots are helpful to show multivariate perceptions with a self-assertive number of factors (Chambers et al., 1983). Each plot shows one perception. Ordinarily, radar plots are created in a multi-plot design with more than one star on each page and each

star indicating one perception. These star plots were first utilized by Georg von Mayr in 1877 (Friendly and Denis, 1995). Radar plots are basically suited for strikingly indicating and shared characteristic, or when one diagram is more noteworthy in each factor than another, and fundamentally utilized for ordinal measurements – where factor relates to "better" in some regard, and all factors on a same scale.

Despite its strengths, radar plots are criticized for some pertinent drawbacks. Radar plots have been scrutinized as inadequately suited for settling on exchange of choices – when one plot is more prominent than another on some factors, however less on others. Moreover, it is difficult to make visual comparisons since lengths of changed spokes, since radial distances are difficult to pass judgment, however concentric circles help as grid lines. Rather, one may utilize a basic line plot, especially for time series.

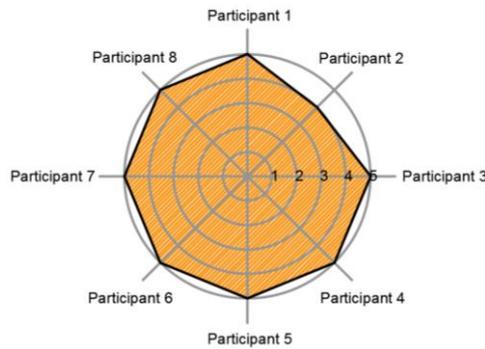
The participants were asked to rank five different statements with respect to importance scale shown in Table 5. According to the responses of the participants, radar plots shown in Figure 7 have been generated.

Table 5 – Grading Key

<b>Ranking</b>	<b>Meaning</b>
5	Strongly agree
4	Agree
3	Moderate
2	Disagree
1	Strongly disagree

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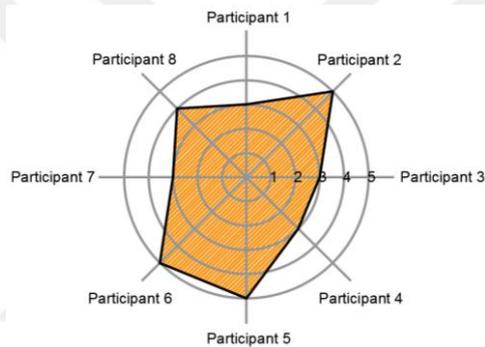
**Statement:** The airport projects are large and complex.



**Responses:** The participants seem to agree on the statement that the ACPs are large and complex compared to other types of construction projects.

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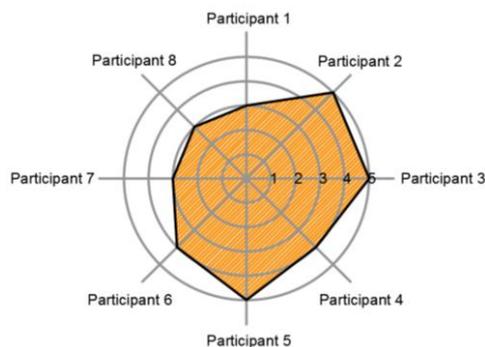
**Statement:** There is extreme time constraint for airport projects.



**Responses:** The responses on this statement indicate that the participants generally agree that there is a great time pressure on them during ACPs as they rank the statement in a range of 3-moderately agree to 5-strongly agree.

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**Statement:** The parties involved should be sufficiently experienced for airport projects.



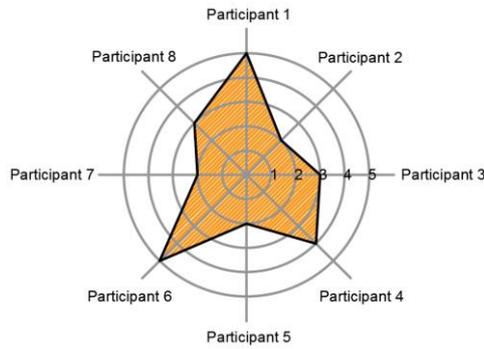
**Responses:** While around half of the participants are neutral if the experience matters for ACPs, the other half of them agree on the statement.

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Figure 7 – Radar charts

**Statement:** The airport projects are sensitive to regulatory changes.

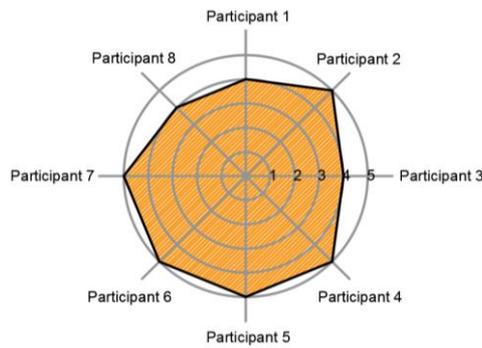
**Responses:** The responses vary for this statement. 37.5% of the participants do not think that the ACPs are sensitive to the regulatory changes. Besides, 25% of the participants are neutral. The reason behind this kind of response could be that most of the ACPs are protected by the investors by laws, and investors take the responsibilities if regulatory changes affect the ACPs by means of claims and change orders.



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**Statement:** Usage of new technologies is required for airport construction projects.

**Responses:** The participants seem to agree on the statement that the implementation of new technologies is essential for airport construction projects.



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Figure 7 – Radar charts (continued)

### **4.3. Analytical Network Process**

Finally, the stage of assessing information is reached since risk identification is complete.

Assessment of the risks aims to increase the understanding of the project in general. Besides, identifying alternative methods to handle the risks is another aim of risk assessment which ensures that uncertainties and risks are adequately considered in a systematic way (Wideman, 1992).

ANP is a generalization of the AHP (Analytic Hierarchy Process). This method is defined by Saaty (2005) as “a multicriteria theory of measurement used to derive relative priority scales of absolute numbers from individual judgments that also belong to fundamental scale of absolute numbers”. In this application, the experts reflect their experiences making pairwise comparisons among the compared factors (Saaty, 2005).

The most outstanding difference between ANP and AHP is that, in ANP there are no presumptions about the independence of elements which are at higher levels from lower ones (Saaty, 2005). Comparing to AHP method, ANP is less used in risk management. There are four steps in ANP method (Görener, 2012):

1. Structuring model of the problem.
2. Making pairwise comparison.
3. Forming of a higher level of matrix.
4. Synthesizing the parameters and the factors, and selecting the best ones.

In this stage it is good to illustrate the following figure which compares the AHP and the ANP methods.

Figure 8 – Different structures of the AHP and ANP methods illustrates the different structures of the AHP and ANP methods.

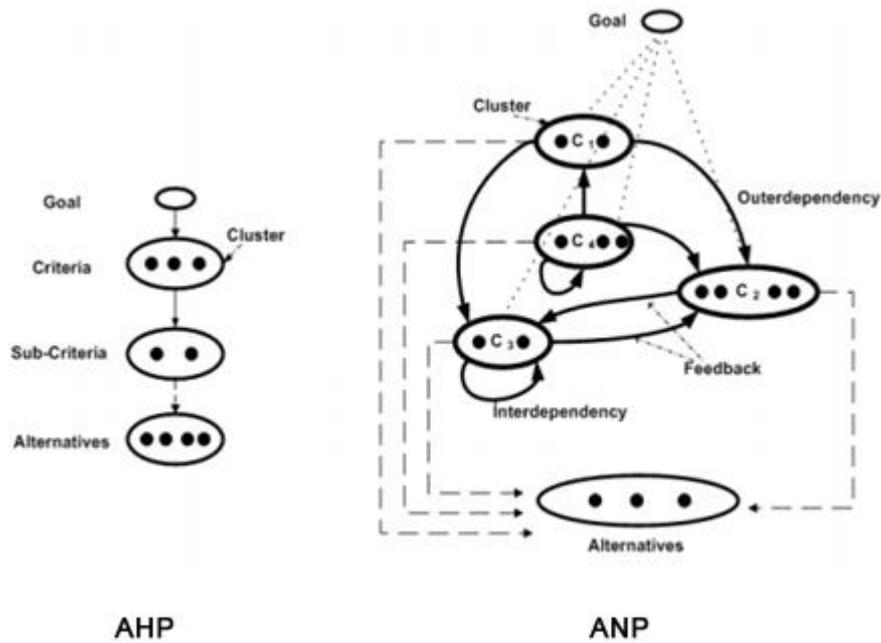


Figure 8 – Different structures of the AHP and ANP methods

As shown in Figure 8, hierarchies have their own goals. When available alternatives are put in the model, a cluster that shows the choices of the decision will appear clearly. Additionally, the linear structure, which is from top to down, is one of the major characteristics of AHP, and its lower levels do not feed the higher levels back. Moreover, there is a loop at the lower levels showing that each alternative at this level relies upon itself; thus, the components are said to be independent. Despite what might be expected, a network enables interactions from one cluster to the other (external dependence), as well as in opposite direction, specifically from next cluster or by transition among mid-clusters through a way that relies upon the objective of the model and dependence level inside the network. Additionally, the network might be produced using a hierarchy by expanding its relationships step by step, to create the model by interfacing segments as required, and its parts have internal dependence circle.

In networks, priority vectors are determined and incorporated into it to its own column vector in supermatrix of contacts regarding the control measure. In the Analytic Network Process, each criterion must be weighted. It is good to know that the weights cannot be solid by basically appointing numbers to the criteria, however, the criteria

should be compared with respect to its goal (Bu-Qammaz et al., 2009). As shown in Figure 8, the ANP first includes in by breaking down a perplexing problem with an assortment of impacts and afterward pulling it back together by utilizing the weights of these impacts.

On the contrary, the main area of interest of both processes, is relative importance. It is good to bear in mind that, in ANP, experts are asked to make the pairwise comparisons. Generally speaking, experts are after the criteria having greater importance compared to the other ones. In other words, experts are after determining which one of two factors are affected more by the given criterion (Saaty, 2003). A scale in Table 6, composed of absolute numbers, is used in both processes:

Table 6 – Intensity of importance (Saaty, 2005)

<b>Intensity of importance</b>	<b>Definition</b>	<b>Explanation</b>
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	Importance between 1 and 3
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	Importance between 3 and 5
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	Importance between 5 and 7
7	Very strong or demonstrated importance	An activity is favored very strongly over another, its dominance demonstrated in practice
8	Very very strong	Importance between 7 and 9
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

During this comparison process, experience levels of the experts matter as they are asked to make judgments according to a control criterion previously defined. As control criteria leads to focus on the problem or goal of the ANP, a clear identification of control criteria is essential (Saaty, 2005).

After completing pairwise comparisons in the network with respect to previously selected control criteria, a priority vector and maximum eigenvalues can be computed as a result of the matrices reached. A matrix, called supermatrix, is developed by use of the results of pairwise comparison stage, and it consists of the arrangement of matrices of column priorities. Resulting priorities enable project managers to take required precautions while selecting the best alternative.

Saaty (2005) explained that “comparisons require judgments. Judgments are associated with feelings, feelings with intensities, intensities with numbers, numbers with a fundamental scale, and a set of judgments reflected by a fundamental scale to priorities”. However, in the evaluation process, pairwise comparisons may cause a consistency problem which is mostly indicated by a ratio, called Consistency Ratio (CR). This allows a numeric understanding of inconsistency of the results of pairwise comparisons (Bu-Qammaz et al., 2006). Some authors had suggested ways to determine to CRs (Cheng and Li, 2005), for the model in their study, the consistency with a CR less than 0.10 has been assumed to be satisfying (Saaty, 2003).

The software used in this study is called as “Superdecisions” which is a free tool applied for ANP and AHP. As previously mentioned, ANP has the following components:

1. A control model of categories and sub-categories which monitor the relationships in the network.
2. A model of interactions of clusters and elements.

The model depends on the criterion and each one in the impact network is unique. A limiting supermatrix of this impact is calculated for each control parameter. At that point, every supermatrix is weighted by the need of control parameter and the results are combined by expansion of the control criteria (Saaty, 2003).

#### Control hierarchy:

Control hierarchy guides the experts as being a foundation for pairwise comparisons about relationships (Saaty, 2005). The hierarchical risk breakdown structure for ACPs was constructed by the help of risk categories defined in previous chapters. The composition of risk categories is mostly called as clusters in an ANP model. The risk

factors under each risk category lay within the corresponding cluster, and they are called as nodes.

Criteria (risk categories) and sub-criteria (risk factors) are defined to have a control hierarchy. This hierarchy helps in making pairwise comparisons. Generally, ANP is used to calculate the priorities considering benefits, opportunities, costs, and risks (Bu-Qammaz, 2009).

The control hierarchy for risks in ACPs can be figured as given in Figure 9 considering the risk categories and risk factors mentioned in the previous chapters.



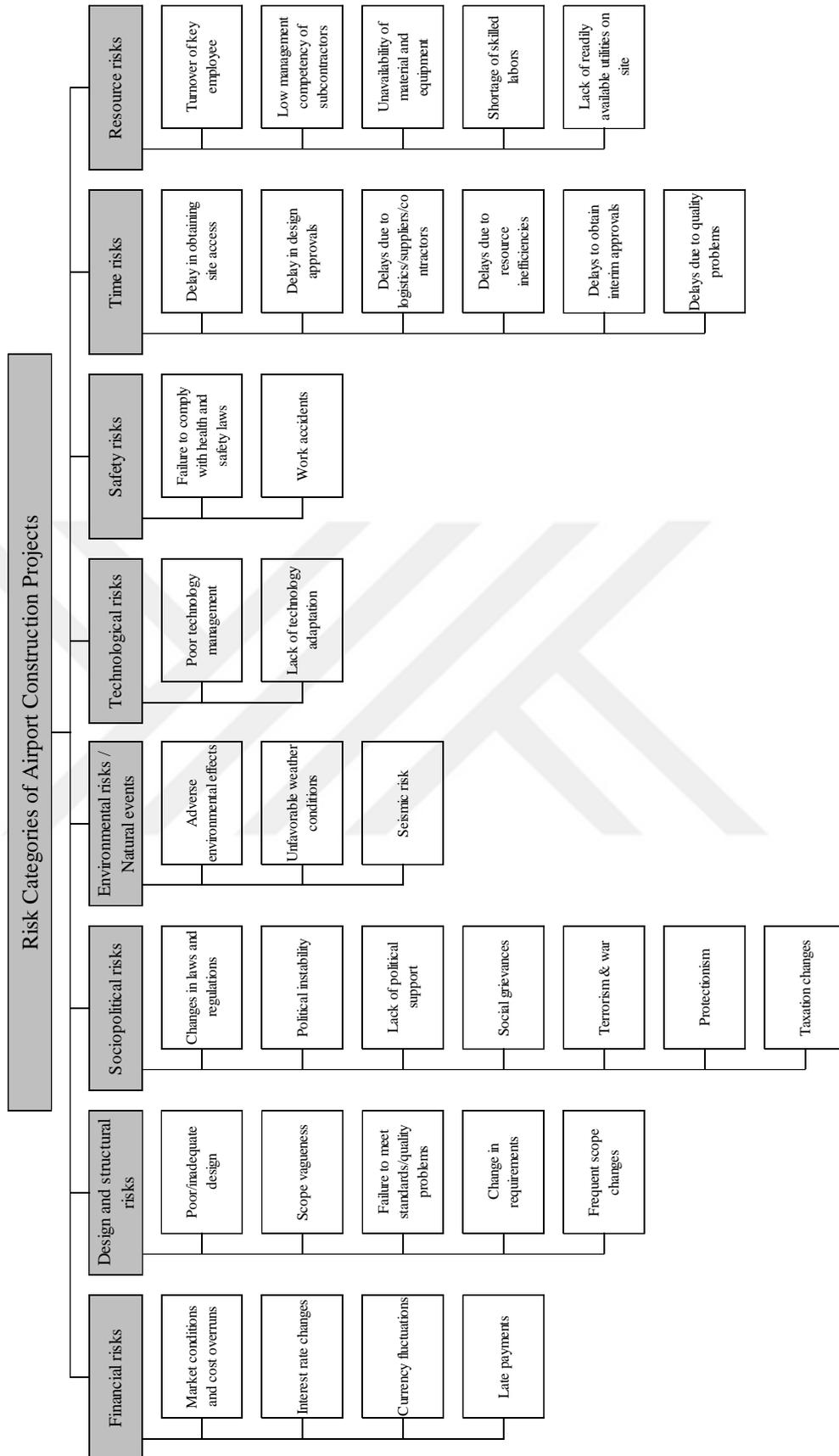


Figure 9 – Hierarchy of the risks identified

### The ANP Model:

In the lights of above-mentioned concepts, the ANP model is implemented to Superdecisions software which is a free tool available for the researchers. Keeping the control hierarchy and its usage in mind, the model and the relationships between each cluster and node are introduced to the Superdecisions ANP model, a software which allows an easy computation for supermatrix of limiting influence and for weighted supermatrix of priorities (Saaty, 2003).

After deciding the cogent groupings as shown in the control hierarchy, the ANP model can easily be developed. The risk factors are introduced as nodes to the model while the risk categories are as clusters. However, Miller (1956) advises not to include more than five to nine elements (which is plus and minus magic number seven) in any cluster or element groups since examinations have demonstrated that it is intellectually difficult for individuals to manage in excess of nine factors at one time and this can result in less exact priorities. Obeying this principle, in our control hierarchy, there are eight risk categories, and number of risk factors beneath each risk category changes from two to seven. Another important point is that the risk categories and risk factors should be comparable to each other. By these important concepts in mind, the ANP models, even though they are complex, can be generated in Superdecisions-like softwares.

Table 7 shows the risk categories investigated in this study with their abbreviations which are used for simplicity during the pairwise comparisons.

Table 7 – The risk categories

Abbreviation	Risk category (Clusters)
DR	Design and structural risks
ER	Environmental risks/Natural events
FR	Financial risks
RR	Resource risks
SR	Safety risks
SP	Sociopolitical risks
TC	Technological risks
TR	Time risks

Table 8 shows the nodes, that is to say risk factors, with their abbreviations:

Table 8 – The risk factors

<b>Abr.</b>	<b>Risk category (Clusters)</b>	<b>Abr.</b>	<b>Risk Factor (Nodes)</b>
DR	Design and structural risks	DR1	Poor/inadequate design
		DR2	Scope vagueness
		DR3	Failure to meet standards/quality problems
		DR4	Change in requirements
		DR5	Frequent scope changes
ER	Environmental risks/Natural	ER1	Adverse environmental effects
		ER2	Unfavorable weather conditions
		ER3	Seismic risk
FR	Financial risks	FR1	Market conditions and cost overruns
		FR2	Interest rate changes
		FR3	Currency fluctuations
		FR4	Late payments
RR	Resource risks	RR1	Turnover of key employee
		RR2	Low management competency of subcontractors
		RR3	Unavailability of material and equipment
		RR4	Shortage of skilled labors
		RR5	Lack of readily available utilities on site
SP	Sociopolitical risks	SP1	Changes in laws and regulations
		SP2	Political instability
		SP3	Lack of political support
		SP4	Social grievances
		SP5	Terrorism & war
		SP6	Protectionism
		SP7	Taxation changes
SR	Safety risks	SR1	Failure to comply with health and safety laws
		SR2	Work accidents
TC	Technological risks	TC1	Poor technology management
		TC2	Lack of technology adaptation
TR	Time risks	TR1	Delay in obtaining site access
		TR2	Delay in design approvals
		TR3	Delays due to logistics/suppliers/contractors
		TR4	Delays due to resource inefficiencies
		TR5	Delays to obtain interim approvals
		TR6	Delays due to quality problems

This study aims to provide an accurate estimation on the priorities of risk factors related with ACPs from the contractors' point of view. Therefore, a cluster named "00: Goal" is first introduced in the model with a node inside named "00: Risks in Airport Construction Projects". The above-mentioned clusters are the "criteria", and the risk factors are the nodes for the ANP model. However, having an aim to figure out the most important risk factors, this study does not require an "alternative" cluster. The network setup used in ANP is a unique network that includes clusters and their nodes in the same screen, and all questions to make comparison are asked to find out which risk factor is more important among others considering the risks in ACPs.

In Figure 10 the loops in a cluster are shown, and these loops represent the "inner dependence" between the nodes. The nodes are pairly compared with the parent node by the command named Pairwise Comparisons under Assess/Compare button or simply by F5 button.

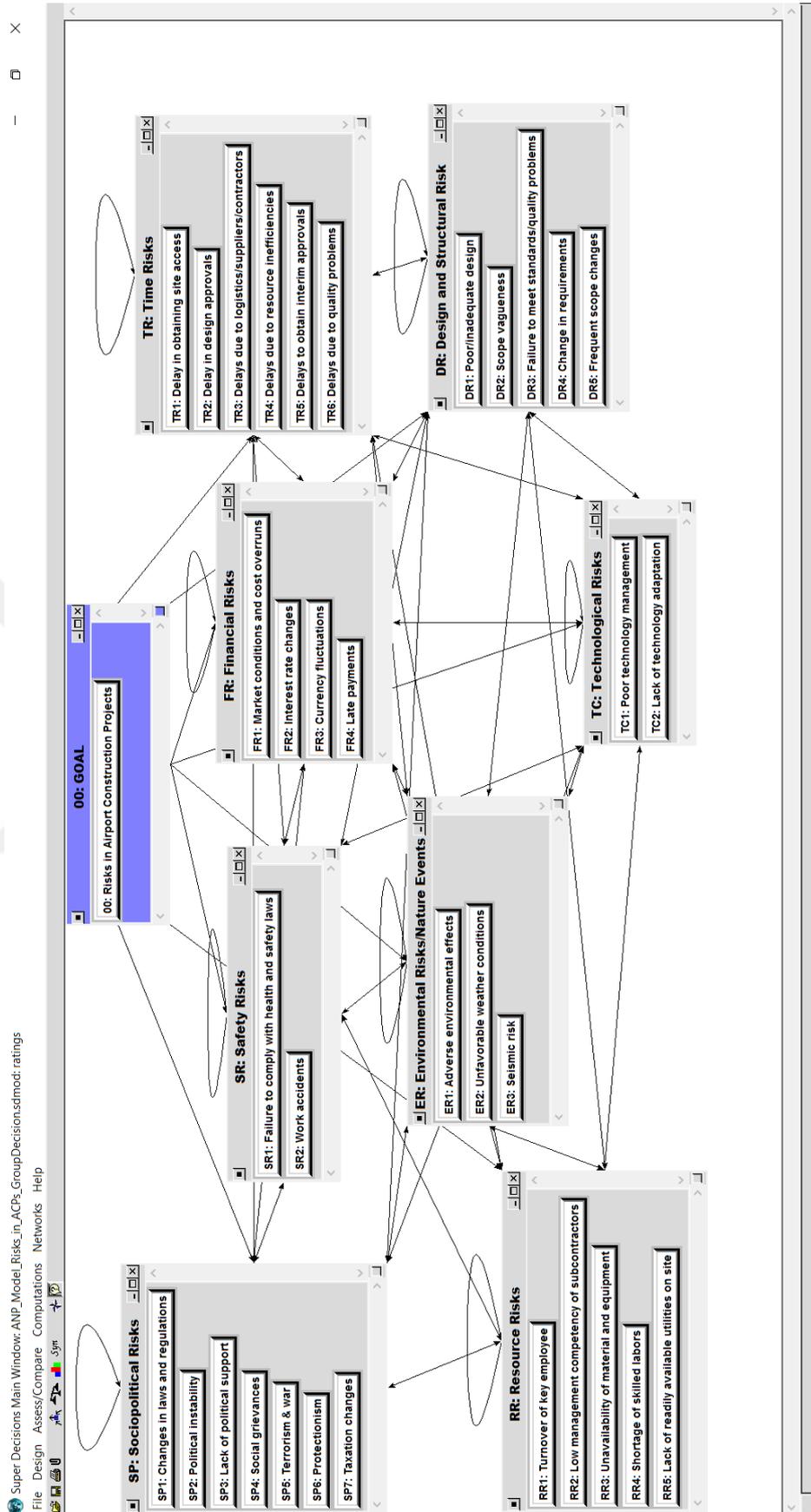


Figure 10 – ANP Setup in Superdecisions Software

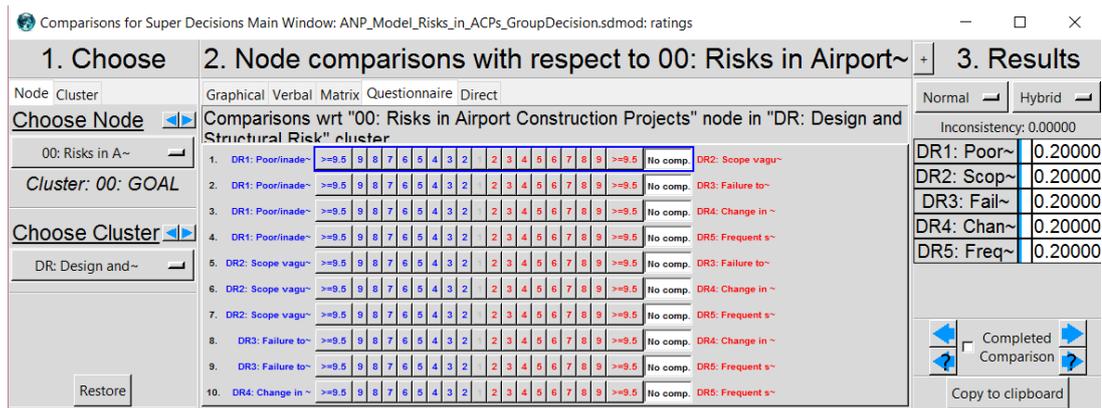


Figure 11 – Pairwise comparisons Screen in Superdecisions Software

Thankfully, all of 8 members of the focus group with whom the semi-structured interviews were conducted have also participated to ANP’s pairwise comparison stage of this study, and shared their experiences on ACPs. For simplicity, a website was prepared and participants were asked to go through it. The format of pairwise comparison was prepared very similar to the Questionnaire Mode used in Superdecisions software as shown in Figure 11:

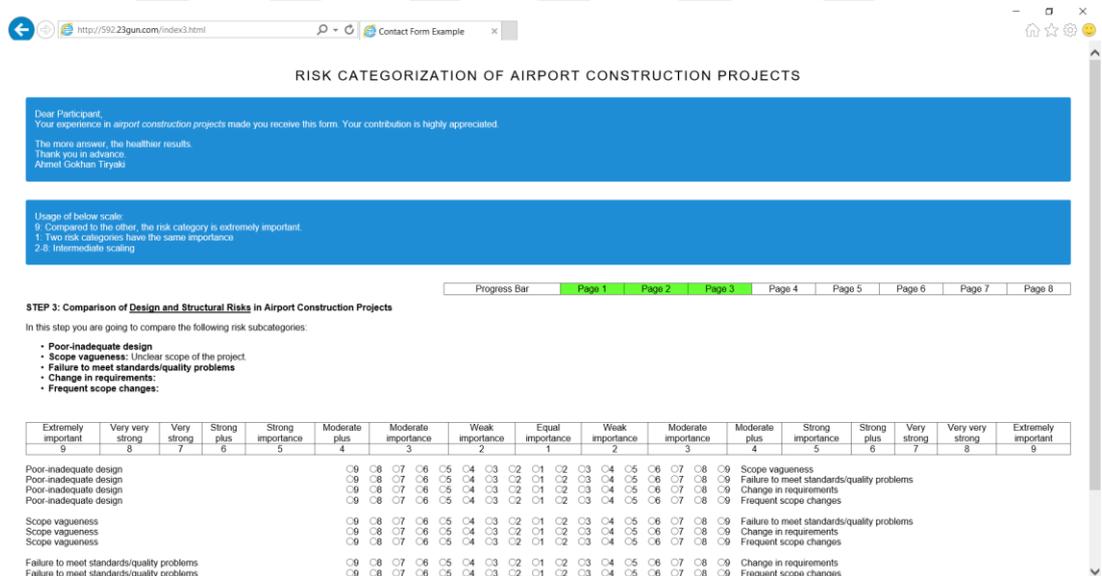


Figure 12 – Questionnaire for collecting inputs

However, in an ANP only one implementation can be done for each pairwise comparison. Being aware that the all 8 participants are experienced in ACPs, they shared their responses to each pairwise comparison, the need of reaching to a

consensus was satisfied. To reach to a consensus, there are several methods including followings (Shih, 2010; Lai et al., 2002; Jharkharia and Shankar, 2007):

- Brainstorming consensus,
- Voting or compromising,
- Borda count,
- Hare method,
- Method of pairwise comparison,
- Method of approval voting.

Another approach to reach consensus is to calculate geometric means of pairwise comparisons, and since geometric mean is used in this study, a brief explanation is given in the following section.

Geometric mean: According to Saaty (2008), followings should be taken into consideration in making group decisions:

1. A single judgement which can represent a common judgement should be gathered by utilizing individual evaluations.
2. Individual opinions should lead to a group choice.

Saaty (2008) underlines that expert judgments must be synthesized so that the judgements indicate a common understanding, and calculating geometric means of the pairwise comparisons is the only way to make this synthesis.

The geometric mean for a set of  $n$  numbers is calculated by the following formula, and this allows the analyzer to handle limitless number of pairwise comparisons (Ehrgott, 2010).

$$\text{Geometric mean} = \left( \prod_{i=1}^n x_i \right)^{1/n} = \sqrt[n]{x_1 x_2 \dots x_n}$$

Geometric mean is a convenient application to combine individual judgements to gather the group decision for each pairwise comparison (Byun, 2001). On the other hand, there are some disadvantages of using geometric mean to reach group decision.

1. Geometric mean cannot be calculated if any of the observations are zero or negative. Although participants cannot make pairwise comparisons by zero nor negative values, they are allowed to skip any pairwise comparison they are asked to complete. In such cases, geometric mean is calculated by using

other ranked comparisons. For example, if one of the eight participants skipped one pairwise comparison, geometric mean of above mentioned pairwise comparison is calculated by use of seven rankings. Due to this reason, participants were encouraged to complete all pairwise comparisons.

2. Its calculation is rather difficult and if the number of the sample size is high, a convenient calculation tool might be required. In this study, MS Excel has been used to calculate geometric means of the pairwise comparisons.
3. Geometric mean may not coincide with any of the rankings made by the participants.

Byun (2001), Lai et al. (2002), Ngai (2003), and Erdogmus et al. (2006) used geometric mean for their group decision problems in their studies. The same method is also used in this study. For example, for “Design and Structural Risks” cluster results are shown in Table 9 and rankings in column named “In the Model” show how many times the second risk factor is important than the first risk factor. The geometric means for each pairwise comparison are calculated by the use of MS Excel software.

Table 9 – Geometric means for design and structural risks

Risk Factor	Prt: 1	Prt: 2	Prt: 3	Prt: 4	Prt: 5	Prt: 6	Prt: 7	Prt: 8	Risk Factor
DR1	6	1	5	9	2	7	0.5	3	DR2
DR1	1	3	5	0.14	2	1	0.5	0.5	DR3
DR1	4	2	1	0.14	2	5	1	1	DR4
DR1	5	2	1	0.13	2	5	3	2	DR5
DR2	0.14	1	1	0.13	3	0.2	2	1	DR3
DR2	1	1	1	0.14	3	5	2	2	DR4
DR2	4	1	1	0.13	2	5	3	5	DR5
DR3	7	1	1	3	0.5	7	0.5	3	DR4
DR3	8	1	1	2	7	3	5	5	DR5
DR4	2	2	1	1	0.5	1	3	3	DR5



Risk Factor	Geometric Mean	In the Model	Risk Factor
DR1	2.95	DR1: 3	DR2
DR1	1.01	DR1: 1	DR3
DR1	1.35	DR1: 1	DR4
DR1	1.72	DR1: 2	DR5
DR2	0.62	DR3: 2	DR3
DR2	1.30	DR2: 1	DR4
DR2	1.72	DR2: 2	DR5
DR3	1.80	DR3: 2	DR4
DR3	2.89	DR3: 3	DR5
DR4	1.44	DR4: 1	DR5

The geometric means of each pairwise comparison are implemented in the ANP model, as shown in Figure 13 produced in Superdecisions software in a Questionnaire format and the “Completed” checkbox is checked:

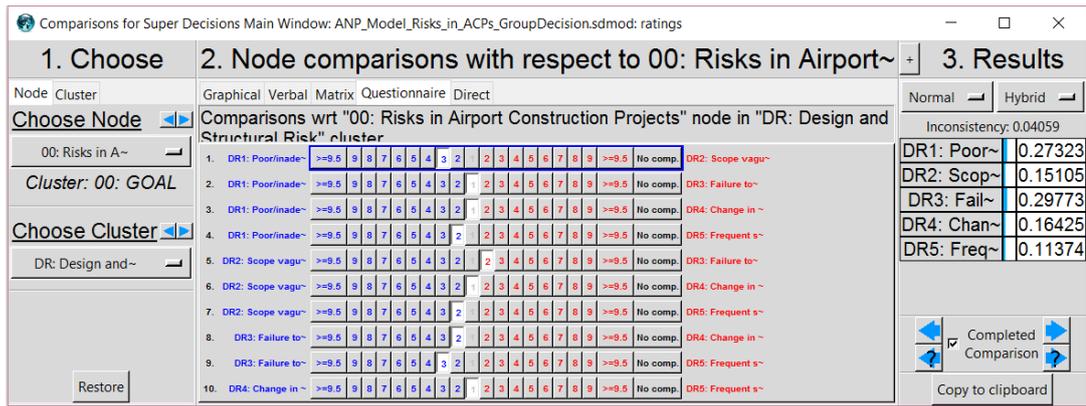


Figure 13 – Implementation of pairwise rankings

The inconsistency is computed by the software and it is 0.04059 which is below 0.10 and inconsistency ratios below 0.10 are considered to be satisfactory (Saaty, 2003).

Supermatrices:

According to Saaty (2005), to explain the supermatrix, a system of  $N$  clusters should be considered. There is interaction of the inner elements in each cluster, or they are affected by some or all elements in that cluster or in the other clusters with respect to a selected criterion which guides the relationships in the network. Saaty assumes a cluster named  $t$ , denoted by  $C_t$ , where  $t = 1, \dots, N$ , has  $n_h$  elements, which are denoted by  $e_{t1}, e_{t2}, \dots, e_{tnk}$  (Bu-Qammaz et al., 2009). (Figure 14 and Figure 15)

A priority vector is gathered by use of pairwise comparisons, and this vector shows the interactions of a given set of elements in a component on another element in the network (Bu-Qammaz et al., 2009). When an element has no impact on another, it is said that its influence is not put in the system, therefore, it is assigned zero (Saaty, 2005). The priority vectors are derived using matrices reached according to the results of pairwise comparison and these matrices are put into the columns of the supermatrix which represents the priorities of influences of a factor on the left of the matrix on a factor at the top of the matrix. In the following figures, cluster  $C_i$  is represented at the side of the supermatrix which includes all the priority vectors derived for nodes that are "parent" nodes in the cluster  $C_i$  (Saaty, 2005).

$$W = \begin{matrix} & \begin{matrix} C_1 & C_2 & \dots & C_N \end{matrix} \\ \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_N \end{matrix} & \begin{bmatrix} e_{11} & e_{21} & \dots & e_{N1} \\ e_{12} & e_{22} & \dots & e_{N2} \\ \vdots & \vdots & \dots & \vdots \\ e_{1n_1} & e_{2n_2} & \dots & e_{Nn_N} \\ \vdots & \vdots & \dots & \vdots \\ e_{2n_1} & e_{2n_2} & \dots & e_{2n_N} \\ \vdots & \vdots & \dots & \vdots \\ e_{Nn_1} & e_{Nn_2} & \dots & e_{Nn_N} \end{bmatrix} \end{matrix}$$

Figure 14 – General presentation of the Supermatrix

$$W_{ij} = \begin{bmatrix} W_{i1}^{(j_1)} & \dots & W_{i1}^{(j_{n_j})} \\ \vdots & \ddots & \vdots \\ W_{in_i}^{(j_1)} & \dots & W_{in_i}^{(j_{n_j})} \end{bmatrix}$$

Figure 15 – General presentation of matrix in the Supermatrix

A separate control hierarchy, which is composed of the criteria and the priorities, is required so that its components can be shown. Thus, factors for every single criterion are compared with respect to their relative influences on one another at the highest point of the supermatrix. This will prompt built priorities to weight the block matrices of columns of eigenvector under that segment in the supermatrix (Saaty, 2005).

Weighted supermatrix is a stochastic matrix, to figure out limiting priorities, and gathered by weighing the components of the unweighted supermatrix.

Bu-Qammaz et al. (2009) states that “initially the supermatrix should be reduced to a matrix before taking the limit, where each of its column sums to unity, which will result in a matrix which is called a column stochastic matrix”. Supermatrix is not normally stochastic since several eigenvectors whose entries in normalized form sum to one its columns, are made up of, and therefore, each column in the supermatrix sums to the number of its nonzero eigenvectors. Because of this reason, a comparison is needed to be conducted for its clusters to convert this supermatrix to a stochastic form (Bu-Qammaz et al., 2009). The clusters are compared according to their impact on each other with respect to the general control criterion which has been considered, and thus, in case of several control criteria it is needed to repeat this process several times for a decision problem once for each control criteria. Fortunately, several comparison

matrices are needed for each control criteria which means each matrix is used to compare the influence of all the clusters on a given cluster to which they are connected. This will result in an eigenvector of influence of all the clusters on each cluster. As previously explained, if there is no impact, vector will have zero value. The priority of a component of such an eigenvector used to weight all the elements in the block of the supermatrix that corresponds to the elements of both influencing and the influenced cluster. The outcome is a stochastic supermatrix (Bu-Qammaz et al., 2009).

Superdecisions software computes the supermatrices named unweighted supermatrix, weighted supermatrix, and limit matrix which are the three types of computations executed under Computations button.

1. Unweighted supermatrix: The supermatrix in which the priorities calculated by pairwise comparisons entered. To reach the supermatrix, the “Unweighted supermatrix” under “Computations” tab is selected. A small part of the graphical view of 35x35 unweighted supermatrix, generated by Superdecisions software, is shown in Figure 16:

Cluster Node Labels		00: GOAL	DR: Design and Structural Risk					ER: Environmental Risks/Nature Events	
		00: Risks in Airport Construction Projects	DR1: Poor/inadequate design	DR2: Scope vagueness	DR3: Failure to meet standards/quality problems	DR4: Change in requirements	DR5: Frequent scope changes	ER1: Adverse environmental effects	ER2: Unfavorable weather conditions
00: GOAL	00: Risks in Airport Construction Projects	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
DR: Design and Structural Risk	DR1: Poor/inadequate design	0.273230	0.000000	0.281878	0.406344	0.355051	0.316498	0.271355	0.271355
	DR2: Scope vagueness	0.151050	0.194799	0.000000	0.208144	0.144949	0.151661	0.130295	0.130295
	DR3: Failure to meet standards/quality problems	0.297728	0.433577	0.367731	0.000000	0.355051	0.328941	0.303485	0.303485
	DR4: Change in requirements	0.164253	0.194799	0.199971	0.237233	0.000000	0.202900	0.165615	0.165615
	DR5: Frequent scope changes	0.113738	0.176826	0.150420	0.148278	0.144949	0.000000	0.129250	0.129250
ER: Environmental Risks/Nature Events	ER1: Adverse environmental effects	0.333333	0.333333	0.333333	0.333333	0.333333	0.333333	0.000000	0.500000
	ER2: Unfavorable weather conditions	0.333333	0.333333	0.333333	0.333333	0.333333	0.333333	0.500000	0.000000

Figure 16 – Unweighted supermatrix

2. Weighted supermatrix: This kind of matrix is derived by use of multiplication of risk factors in a component of the unweighted supermatrix by the cluster weight it corresponds to. A small part of the graphical view of 35x35 weighted supermatrix, generated by Superdecisions software, is shown in Figure 17:

Cluster Node Labels		00: GOAL	DR: Design and Structural Risk					ER: Environmental Risks/Nature Events	
		00: Risks in Airport Construction Projects	DR1: Poor/inadequate design	DR2: Scope vagueness	DR3: Failure to meet standards/quality problems	DR4: Change in requirements	DR5: Frequent scope changes	ER1: Adverse environmental effects	ER2: Unfavorable weather conditions
00: GOAL	00: Risks in Airport Construction Projects	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
DR: Design and Structural Risk	DR1: Poor/inadequate design	0.076660	0.000000	0.079086	0.114008	0.099617	0.088800	0.076134	0.076134
	DR2: Scope vagueness	0.042380	0.054655	0.000000	0.058399	0.040668	0.042551	0.036557	0.036557
	DR3: Failure to meet standards/quality problems	0.083533	0.121649	0.103174	0.000000	0.099617	0.092291	0.085149	0.085149
	DR4: Change in requirements	0.046085	0.054655	0.056106	0.066561	0.000000	0.056928	0.046467	0.046467
	DR5: Frequent scope changes	0.031912	0.049612	0.042203	0.041602	0.040668	0.000000	0.036264	0.036264
ER: Environmental Risks/Nature Events	ER1: Adverse environmental effects	0.030012	0.030012	0.030012	0.030012	0.030012	0.030012	0.000000	0.045018
	ER2: Unfavorable weather conditions	0.030012	0.030012	0.030012	0.030012	0.030012	0.030012	0.045018	0.000000

Figure 17 – Weighted supermatrix

- Limit matrix: The final priorities are shown in the column under the goal. Raising the weighted supermatrix to powers yields the limit matrix from which the final answers are extracted. When the columns of numbers become identical, it is said that the limit matrix has been reached. Limit matrix provides the priorities for the different subcategories in the network. Since the columns of the limit matrix are all identical, the priorities for all the elements in any cluster can be read directly from any column.

There are several ways to compute limit matrix. Fortunately, Superdecisions software allows computation of limit matrix by these calculations, separately. In this study, Calculus Type of calculation of limit matrix has been preferred and Adams (2001) summarize the Calculus Type limit matrix calculation as in the following equation:

$$limitMatrix = \sum_{i=1}^L S^i$$

Where  $S$  is the scaled supermatrix and  $L$  is the number of levels in the hierarchy.

Other methods to calculate limit matrix are Scaling by Scalar, New Hierarchy (with and without limit), Identity at Sinks, Sinks Formula (straight normalize and normalize  $limitB$ ), Pre-2001 and Pre-2000. Last two components of this

list (Pre-2001 and Pre-2000) are kept for historical purposes only, but should not be used in calculation of limit matrix.

A small part of the graphical view of 35x35 limit matrix, which is generated by Superdecisions software by use of calculus type is shown in Figure 18:

Cluster Node Labels		DR: Design and Structural Risk					ER: Environmental Risks/Nature Events		
		00: GOAL 00: Risks in Airport Construction Projects	DR1: Poor/inadequate design	DR2: Scope vagueness	DR3: Failure to meet standards/quality problems	DR4: Change in requirements	DR5: Frequent scope changes	ER1: Adverse environmental effects	ER2: Unfavorable weather conditions
00: GOAL	00: Risks in Airport Construction Projects	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
DR: Design and Structural Risk	DR1: Poor/inadequate design	0.075604	0.075604	0.075604	0.075604	0.075604	0.075604	0.075604	0.075604
	DR2: Scope vagueness	0.038916	0.038916	0.038916	0.038916	0.038916	0.038916	0.038916	0.038916
	DR3: Failure to meet standards/quality problems	0.082931	0.082931	0.082931	0.082931	0.082931	0.082931	0.082931	0.082931
	DR4: Change in requirements	0.047540	0.047540	0.047540	0.047540	0.047540	0.047540	0.047540	0.047540
	DR5: Frequent scope changes	0.036998	0.036998	0.036998	0.036998	0.036998	0.036998	0.036998	0.036998
ER: Environmental Risks/Nature Events	ER1: Adverse environmental effects	0.029961	0.029961	0.029961	0.029961	0.029961	0.029961	0.029961	0.029961
	ER2: Unfavorable weather conditions	0.029961	0.029961	0.029961	0.029961	0.029961	0.029961	0.029961	0.029961

Figure 18 – Limit matrix

The “Priorities” command under “Computations” menu displays the priorities in two different ways: as appeared in the limit matrix, and with the priorities normalized by cluster.

Table 10 – Priorities of risk factors

Abr.	Risk Factor (Nodes)	Normalized by		Ranking
		Cluster (A)	(B)	
DR1	Poor/inadequate design	0.26811	0.075604	3
DR2	Scope vagueness	0.13801	0.038916	9
DR3	Failure to meet standards/quality problems	0.29409	0.082931	2
DR4	Change in requirements	0.16859	0.047540	7
DR5	Frequent scope changes	0.13120	0.036998	10
ER1	Adverse environmental effects	0.33333	0.029961	15
ER2	Unfavorable weather conditions	0.33333	0.029961	14
ER3	Seismic risk	0.33333	0.029961	13
FR1	Market conditions and cost overruns	0.21035	0.045577	8
FR2	Interest rate changes	0.09380	0.020324	17
FR3	Currency fluctuations	0.29010	0.062858	4
FR4	Late payments	0.40575	0.087916	1
RR1	Turnover of key employee	0.19695	0.013671	23
RR2	Low management competency of subcontractors	0.19025	0.013206	25
RR3	Unavailability of material and equipment	0.28019	0.019449	18
RR4	Shortage of skilled labors	0.21350	0.014820	22
RR5	Lack of readily available utilities on site	0.11910	0.008267	30
SP1	Changes in laws and regulations	0.06079	0.004852	34
SP2	Political instability	0.10336	0.008250	31
SP3	Lack of political support	0.07714	0.006157	33
SP4	Social grievances	0.07770	0.006202	32
SP5	Terrorism & war	0.42056	0.033567	11
SP6	Protectionism	0.12848	0.010255	29
SP7	Taxation changes	0.13196	0.010532	28
SR1	Failure to comply with health and safety laws	0.50000	0.057653	6
SR2	Work accidents	0.50000	0.057653	5
TC1	Poor technology management	0.65166	0.030664	12
TC2	Lack of technology adaptation	0.34834	0.016391	21
TR1	Delay in obtaining site access	0.13679	0.013660	24
TR2	Delay in design approvals	0.26039	0.026004	16
TR3	Delays due to logistics/suppliers/contractors	0.12311	0.012294	27
TR4	Delays due to resource inefficiencies	0.17205	0.017182	20
TR5	Delays to obtain interim approvals	0.12415	0.012398	26
TR6	Delays due to quality problems	0.18351	0.018326	19

The following graphical format in Figure 19 helps visualizing the results given in Table 10:

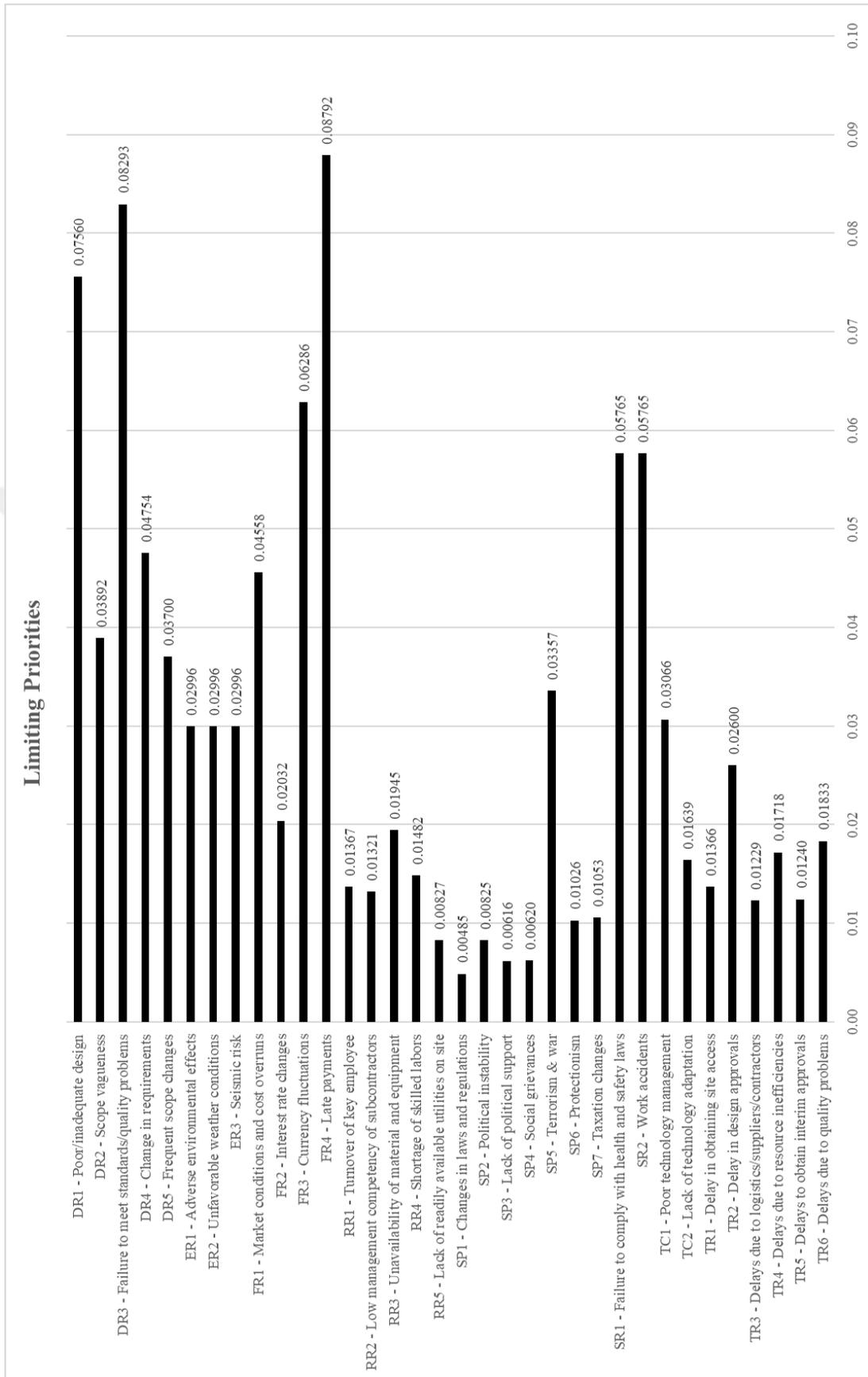


Figure 19 – Priorities of risk factors

The above priorities generated by Superdecisions software and the rankings are allocated for each risk factor with respect to their limiting priority values. It is good to have a look at the cluster priorities, as well, which is shown in Figure 20.

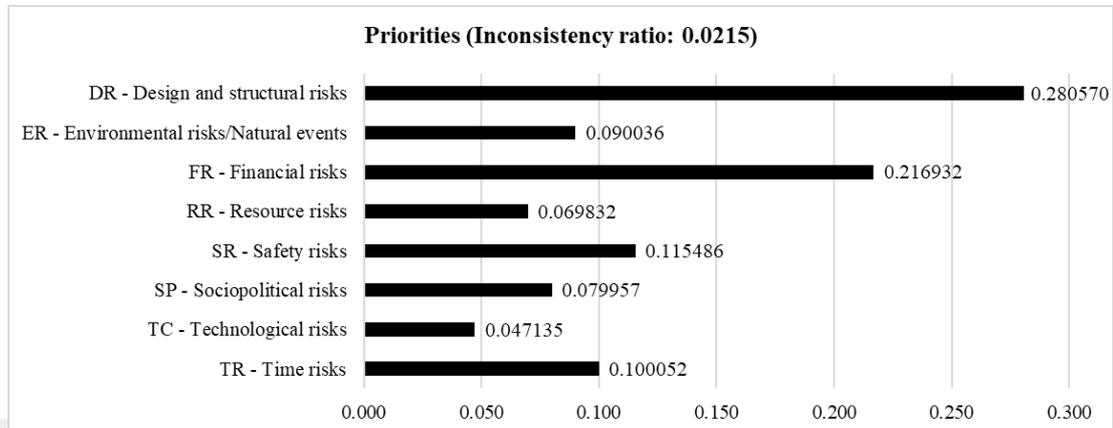


Figure 20 – Priorities of risk categories

After computing priorities by Superdecisions software, it is observed in Figure 20 that design and structural risks category stands to be the most critical risk category for ACPs. This shows that decision makers should take necessary precautions to avoid these risks which are poor/inadequate design, scope vagueness, failure to meet standards/quality problems, change in requirements, and frequent scope changes.

It will be good to continue with the most important risk factor which is late payment risk. Like other construction projects, ACPs are the projects with an aim of short time profit. There is no doubt that in ACPs payment is mostly needed for materials, labor, plant, subcontractors', preliminaries and general overheads spent during the progress of the work (Odeyinka and Yusif, 1998). Contractors usually obey the principle of earn&pay. In other words, they claim payment for the works completed on time, and pay to the subcontractors which contributed for the completed work. Besides, in some circumstances, the opposite of this also valid. That is, contractors first pay for the goods and materials to be used to execute the works and claim the payment in accordance with the completed works. In this case, short delays, less than a week, in payment are considered to be acceptable (Mei and Abdul Rahman, 2010).

A probability of negative cash flows occurs if the flow of money is delayed during projects. It may lead to contractors requiring urgent funding to handle the shortage in the cash. Easy to inference that late payments affect time, cost and quality (Ye and Abdul Rahman, 2010). On the contrary, some of the decision makers may believe that late payment can be acceptable (Cotter, 2005). In the construction industry, late payment risk can be formidable since it will have a great impact on cash flows which are critical in construction industry because of comparatively long duration of the projects. Any kind of delays on payments will have impact on cash flows leading major impacts on the project (Ameer, 2006). “Once a payment problem starts to expand, it typically gets worse over time” says Gregory (2007) on late payments.

In some cases, companies shall make payments for their financial liabilities, for example to the subcontractors, before being paid for the work done by the clients. This results in negative cash flows, and having negative cash flows is likely to cause slightly higher risks to face with financial problems compared to the other factors, and severe negative cash flows may also cause construction companies to their closures. These financial problems may also occur for even profitable projects if they have negative cash flows.

Construction companies must prepare their payment request certificates in a timely manner in order to minimize the risk of having negative cash flow. Another way to prevent the negative cash flow is to make subcontract agreements or purchase orders in back to back basis, which will allow contractors to make payments after being paid by their clients.

## 5. Discussion, Contribution

Throughout this study, an intensive literature review has been conducted by investigating a wide range of articles. During the literature review, a comprehensive research area with chief potential to contribute toward practical use in the industry has been sought. While conducting literature overview, it has been observed that there is lack of information on construction risk analysis. This discourse is also supported by the findings of other researchers. Furthermore, Baghdadi and Kishk leads (2015) warn the project managers about having insufficient literature regarding to risks in ACPs. Thus, having a professional background and network, the subject of “Risk Assessment for Airport Construction Projects Based on the Experience of Project Managers” has been selected to be studied.

The method of semi-structured interviews has been used to gather information to guide the study. Suitability of the semi-structured interviews for working with focus groups, and a well-defined focus group, helped to find out the major risks. By this method, the thoughts and knowledge of experts about risks and risk management for airport construction projects have been gathered, and moreover, some clues have been obtained about their approaches to airport-construction-project-related risks.

The results of the semi-structured interviews have been used to prepare a detailed questionnaire of Figure 12 to be distributed to respondents. Due to having a good network working for airport construction projects, this target has also been achieved with the answers for the following questions: is it a good way to collect data? And, do the individual concerns reflect the overall risk understanding? There is no doubt that every single airport construction project staff faces different risks in their departments.

As mentioned above, there are several techniques to analyze the risks in the literature: qualitative, quantitative and combined methods. One of the best ways is to analyze the risks using qualitative approaches to guide the prospective ACP contractors. The questions of the questionnaire, in the light of results of semi structured interviews, have been prepared studiously to get results to be handled in selected qualitative method, i.e. Analytic Network Process.

This study has an objective of warning project managers, department managers and experts, who are willing to work for airport construction projects, about the risks and risk management methods. On the other hand, one other aim of this study is to contribute to the literature since it does not have sufficient risk-related studies regarding ACPs.

As previously mentioned, one of the most relevant studies has been executed by Baghdadi and Kishk (2015). While they were only interested in risks in Saudi Arabian ACPs, this study has covered a wider geography under favor of experience level of the focus group. Similar to the study of Baghdadi and Kishk (2015), data in this study has been obtained by literature overview and interviews. Authors chose the methodology of expert judgment as a tool of analyzing the risks. However, in this study, Analytic Network Process has been applied to assess the risks for ACPs.

Baghdadi and Kishk (2015) have proposed a structure of risks inherent in Saudi Arabian ACPs which covers 54 risks under 3 risk categories: Internal Risks, External Risks, Force Majeure Risks. Authors concluded that inadequate scope, payment delays, design changes, bureaucratic problems, and changing demands are the first five most important risks in Saudi Arabian ACPs. On the other hand, 34 risk factors have been assessed under 8 risk categories in this study, and late payments, failure to meet standards/quality problems, poor/inadequate design, currency fluctuations, and work accidents are seemed to be the first five most important risks.

Boateng, Chen and Ogunlana (2015) tried to identify and analyze the risks on large projects and obtained data from the literature and history. They chose analytic network method to analyze their findings. According to the authors, disputes, failure to meet specified standards, project delays of all forms, unfavorable climate conditions, and political indecision are five (out of 47 risks in 5 categories) most important risks.

Abdul Kadir et al. (2005) studied risks for Malaysian residential projects and evaluated and ranked the importance, frequency and severity of project delay factors that affect the construction labor productivity. Authors executed interviews with a total of 100 respondents consisting of 70 contractors, 11 developers, and 19 consultants and figured out that the five most important risks for Malaysian residential projects are material shortage at site, non-payment to suppliers causing the stoppage of material

delivery to site, change order by consultants, late issuance of construction drawing by consultants, and incapability of contractors' site management to organize site activities. This may indicate that ACPs have their own dynamics and risks compared to the residential projects, since the risks in Malaysian residential projects do not very well fit to ACPs. Another reason of this inconsistency is likely to be due to regional changes.

Table 11 summarizes the above-mentioned comparisons in tabular form.

	<b>Baghdadi and Kishk (2015)</b>	<b>Boateng, Chen and Ogunlana (2015)</b>	<b>Abdul Kadir et al. (2005)</b>	<b>This Study</b>
<b>Area of interest</b>	Risks in Saudi Arabian ACPs	Risks in megaprojects	Risks for Malaysian residential projects	Risks in ACPs
<b>Data collection</b>	Literature review Interviews	Literature review Questionnaire	Questionnaire	Literature review Semi-structured interviews Questionnaire
<b>Assessment methodology</b>	Expert judgment	Analytic Network Process	Severity index	Analytic Network Process
<b>Number of risk categories</b>	3	5	1	8
<b>Number of risks</b>	54	47	50	34
<b>5 Most important risks</b>	1. Inadequate scope 2. Payment delays 3. Design changes 4. Bureaucratic problems 5. Changing demands	1. Disputes 2. Failure to meet specified standards 3. Project delays of all forms 4. Unfavourable climate conditions 5. Political indecision	1. Material shortage at project site 2. Non-payment (financial problem) to suppliers causing the stoppage of material delivery to site 3. Change order by consultants causing project delay 4. Late issuance of construction drawing by consultants 5. Incapability of contractor's site management to organise site activities	1. Late payments 2. Failure to meet standards/quality problems 3. Poor/inadequate design 4. Currency fluctuations 5. Work accidents

Table 11 – Comparison of findings with selected studies

It should be noted that risks can be named by the authors in different ways referring to the same risk factor for example problems with design are named as design changes, late issuance of construction drawings or poor design.

It is also observed that problems with payment is found to be an important risk factor by 3 studies out of 4 listed in Table 11.

## **6. Recommendations for Further Studies**

In this thesis, risks for airport construction projects based on the experience of project managers have been studied. Further studies may be carried by use of different techniques, other than semi structured interviews, questionnaires, and Analytic Network Process, to collect and assess the information. Other quantitative methods can also be applied for future studies. On the other hand, the outcome of this study is to identify the major risks for airport construction projects and mitigation methods were not mentioned. Therefore, any mitigation method for those risks affecting airport construction projects can be further studied. Moreover, a larger participant group of individuals, worked in several countries in the world, might be selected to assess the risk not only for African, Eastern European and Asian countries, but also for American and Australian countries.

## 7. Conclusion

Throughout this study it is observed that the methods used in this study, i.e. semi-structured interviews and Analytic Network Process are reliable and commonly used to identify risks. At this point, it is good to warn researchers who are willing to utilize Analytic Network Process that pairwise comparisons reflect the subjective rankings based on the experience levels of the participants. Therefore, different results might be gathered for the identical problems if the members of the focus group are changed. Because of the reason mentioned above, participants of the ANP shall be selected from the ones who have relevant experience in their area. To the best of author's knowledge, this study is one of the first studies which combines these methods together.

As it was mentioned previously, all of the participants in focus group agree that risk identification is required and essential, and a detailed risk identification should be applied for each ACP. This result implies that a detailed risk management study is needed for ACPs as they are strategic projects.

It is a clear outcome of semi-structured interviews that risk changes as the time passes and getting experienced allows investigating minor risks which may create high impact if not dealt with. Furthermore, considering duration, relationships between different disciplines and the integration of the different electronic systems, the understanding of the risk is being changed by time and technological developments.

The participants think that risks in tender stage have more uncertain items compared to the construction stage. In the pretender stage, there are various assumptions related to the project which are realized in a good or bad way during the construction stage. Sometimes, decision makers should accept that they were wrong in their assumptions in tender stage. They believe that risks related with the construction stage should also be considered during tender stage. Because, it is expected that the forecasted risks are realized during execution stage. Considering risks in pretender stages, some of the participants decided not to attend for a tender because of high construction costs, while the others decided the same because of political risks in the country where ACP is located. Risk of terrorism and war, as well as local currency fluctuations, made decision makers not to attend the ACP tenders in certain countries.

Time losses due to stopping the work, psychological results for workers and the management, negative effects on productivity, unforeseen costs, loss of reputation, direct losses due to indemnities, long court periods up to 10 years are some other major risks revealed by semi-structured interviews.

Participants mostly think that historical data for similar projects should be analyzed for the upcoming ACPs. For this purpose, every kind of risks are written on a risk matrix, which is also called as risk register, which allows managers to create a risk map. In this risk map, the impact and the chance of occurrences are noted down.

After completion of semi-structured interviews, the collected information was assessed.

In the lights of literature overview and semi-structured interviews, a control hierarchy consisting of 34 risk factors under 8 categories has been developed. This hierarchy has been fed into Superdecisions software which is a free tool applied for ANP.

As mentioned previously, the control hierarchy and its dependencies has been modelled in Superdecisions software to make pairwise comparisons. Pairwise comparisons show that the most outstanding risk category is Design and structural risks and decision makers should take necessary precautions to avoid these risks which are poor/inadequate design, scope vagueness, failure to meet standards/quality problems, change in requirements, and frequent scope changes. On the other hand, pairwise comparisons gave the result that risk of late payments is the most important risk factor among evaluated 34 factors. As previously mentioned, the concept of “late payment” is very special to construction projects and needs to be studied in detail as it is experienced in every single project. There is no doubt that payments should be made for materials, labor, plant, subcontractors, preliminaries and general overheads spent during the progress of the work. A probability of negative cash flow occurs if the flow of money is delayed during project duration. It may lead the contractors require urgent funding to handle the shortage of the cash.

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## Appendix: Interview Questions

No	Direct Question	Additional Question	Clarifying Question #1	Clarifying Question #2
1	Can you tell me in which category should I introduce you?	<p><b>If Project Manager:</b> - In which projects have you worked as project manager? - Do you have project management certifications?</p> <p><b>If Department Manager/Director:</b> - What was your scope in airport construction projects?  - In which projects have you worked as department manager/director?</p> <p><b>If Stakeholder:</b> - How do you describe being a stakeholder in an airport construction project?</p> <p><b>If Expert/Consultant:</b> - Have you worked on risk identification process while being consultant for airport projects?</p> <p><b>If Other:</b> - May I ask you your involvement in the airport construction projects?</p>	<p>- How long have you worked in this position? - How long do you have this certificate?</p> <p>- Can you expand a little on this?  - How long did you take this responsibility?</p> <p>- Can you expand a little on this?  - Have you been interested in risks on airport construction projects?</p> <p>- Can you expand a little on this?  - How long did you take this responsibility?</p> <p>- Can you expand a little on this?  - How long did you take this responsibility?</p>	<p><b>If less than 1 year:</b> - What is your opinion about risks in airport construction projects? - Do you think the risk identification is required and essential for airport construction projects? - Do you expect that your attitude to the risks will change by time?</p> <p><b>If between 2 to 5 years:</b> - Do you think the risk identification is required and essential for airport construction projects? - How did risk identification methods change comparing to your early years in airport construction projects? - Do you think that your risk understanding will change in the future?</p> <p><b>If more than 5 years:</b> - How did risk identification methods change comparing to your early years in airport construction projects?</p>

No	Direct Question	Additional Question	Clarifying Question #1	Clarifying Question #2
2	Where have the airport construction sites you or your company worked for been located? - Africa - North America - South America - Asia including Middle East - Australia - Europe	<p><b>If only 1 region:</b> - Which risks did you face most?  - What was your risk expectation for your project that region and did you face with your expected risks?</p> <p><b>If more than 2 regions:</b> - Which risks did you face most? - Can you please tell me the understanding of risk in those regions?</p>	<p>- Do you think that the same risks will arise if you work in another region for airport construction projects? - Do they differ from one to another?</p>	

No	Direct Question	Additional Question	Clarifying Question #1	Clarifying Question #2
3	Which risk identification methods are used in your project management team? - Brain-storming sessions - Analysis of historical data for similar projects - Use of industrial check lists - Simulation techniques - Other	<p><b>For any kind of answer:</b></p> <ul style="list-style-type: none"> <li>- What is your restriction to give such an answer?</li> <li>- Do you consider time, accuracy or something else?</li> </ul> <p><b>If other:</b> - If you selected other method, can you please describe it more?</p>	<ul style="list-style-type: none"> <li>- How frequently do you use this method?</li> <li>- Is this method applicable for all airport projects in the world?</li> <li>- Is the risk identification process fully integrated with cost and time management processes?</li> </ul> <p><b>If other:</b> - Can you expand a little on this?  - How frequently do you use this method?</p>	

No	Direct Question	Additional Question	Clarifying Question #1	Clarifying Question #2
4	Can you count at least 3 major risks for airport construction projects? - Financial risks (foreign currency...) - Design and Structural risks (durability...) - Demand/product risks (need for construction...) - Political risks (strikes...) - Environmental risks (harmful construction techniques...) - Technological risks (erection methodologies...) - Geographical risks (location of the airport...) - Geotechnical risks (subsurface unforeseen	<p><b>For any kind of answer:</b></p> <ul style="list-style-type: none"> <li>- Is there any relation between these risks?</li> <li>- Do you think that these risks are inevitable?</li> </ul> <p><b>If other:</b> - If you selected other method, can you please describe it more?</p>		

No	Direct Question	Additional Question	Clarifying Question #1	Clarifying Question #2
5	Please rank the following sentences: 1 – don't agree / 5 – strongly agree a. The airport projects are large and complex. b. There is extreme time constraint for airport projects. c. The parties involved should be sufficiently experienced for airport projects. d. The airport projects are sensitive to regulatory changes. e. Usage of new technologies is required for airport	<p><b>If ranked as 1:</b> - Why do you think so? Do you disagree this?</p> <p><b>If ranked as 5:</b> - Can you please expand it a bit more?</p>		

No	Direct Question	Additional Question	Clarifying Question #1	Clarifying Question #2
6	A special question: Do you think that there is a risk relation between time and budget?	<b>If yes:</b> - How are they related to each other?  <b>If no:</b> - Can you please give your reasons defending your answer?  <b>If other answer:</b> - Can you please share your thoughts on duration and budget effects on airport construction project risk identification?	<b>If yes:</b> - How do they affect risk identification process?	

No	Direct Question	Additional Question	Clarifying Question #1	Clarifying Question #2
7	Are there any other risks that we have not discussed and that you find worrisome?	- Can you expand a little on this?	- Can you give me some examples?	