AN EXPLORATORY STUDY ON COMPLEXITY IN MEGA CONSTRUCTION PROJECTS

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ABSTRACT

AN EXPLORATORY STUDY ON COMPLEXITY IN MEGA CONSTRUCTION PROJECTS

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Megaprojects are known as complex projects that involve high levels of uncertainty. This thesis aims to explore perceived complexity in mega construction projects by lived experiences of project managers. For this purpose, data were obtained through semi-structured interviews with 18 participants from 11 mega construction projects carried out by construction professionals. The data was processed with a grounded theory approach and analyzed using the QSR NVivo qualitative data analysis software. Findings show that while some factors contributing to project complexity stem from the known characteristics of the project, such as size, novelty, and the strategic importance of the project (static complexity factors), others are due to uncertainty stemming from operational, political, economic and financial conditions (emergent complexity factors). In this respect, the findings regarding the grounded theory approach closely matched with the existing literature on factors of project complexity. Research findings also showed that the coexistence of and interdependencies between the complexity factors that reveal a "pattern of complexity" has to be considered to understand complexity level rather than individual complexity factors. This finding reinforces the idea that project complexity should be better conceptualized and assessed by a pattern rather than a list or hierarchy of individual complexity factors. Findings may have some implications for assessment and management of complexity during risk management and developing organizational responses considering the type and level of complexity in mega construction projects.

Keywords: Project Complexity, Megaprojects, Qualitative Data Analysis, Grounded Theory, Construction Management

ÖZ

MEGA İNŞAAT PROJELERİNDE KARMAŞIKLIK ÜZERİNE KEŞFEDİCİ BİR ÇALIŞMA

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Mega projeler, yüksek düzeyde belirsizlik içeren karmaşık projeler olarak bilinmektedir. Bu tez, proje yöneticilerinin yaşanmış deneyimleriyle mega inşaat projelerinde algılanan karmaşıklığı keşfetmeyi amaçlamaktadır. Bu amaçla, veriler, inşaat profesyonelleri tarafından yürütülen 11 mega inşaat projesinden 18 katılımcı ile yarı yapılandırılmış görüşmeler yoluyla elde edilmiştir. Veriler, gömülü teori yaklaşımı ile işlenmiş ve QSR NVivo nitel veri analiz yazılımı kullanılarak analiz edilmiştir. Bulgular, proje karmaşıklığına katkıda bulunan bazı faktörlerin, projenin büyüklüğü, yeniliği ve stratejik önemi (statik karmaşıklık faktörleri) gibi projenin bilinen özelliklerinden kaynaklanırken, diğerlerinin operasyonel, politik, ekonomik ve finansal koşullardan (ortaya çıkan karmaşıklık faktörleri) kaynaklandığını göstermektedir. Bu bağlamda, gömülü teori yaklaşımına ilişkin bulgular, proje karmaşıklığı faktörlerine ilişkin mevcut literatürle yakından eşleşmektedir. Araştırma bulguları, karmaşıklık faktörlerinin bir arada bulunmasının ve karşılıklı bağımlılıklarının yani "karmaşıklık modelininin" bireysel karmaşıklık faktörlerinden ziyade karmaşıklık düzeyini anlamak için dikkate alınması gerektiğini de göstermiştir. Bu bulgu, proje karmaşıklığının, bireysel karmaşıklık faktörlerinin bir listesi veya hiyerarşisi yerine bir modelle daha iyi kavramsallaştırılacağı ve değerlendirileceği fikrini güçlendirmektedir. Bulguların, risk yönetimi sırasında karmaşıklığın değerlendirilmesi ve yönetimi ve mega inşaat projelerinde karmaşıklığın türü ve seviyesi dikkate alınarak kurumsal yanıtların geliştirilmesi kapsamında bazı çıkarımları olabilir.

Anahtar Kelimeler: Proje Karmaşıklığı, Mega Projeler, Nitel Veri Analizi, Gömülü Teori, İnşaat Yönetimi

To my beloved family…

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TABLE OF CONTENTS

ABSTRACT v
ÖZ vii
ACKNOWLEDGMENTS x
TABLE OF CONTENTS xi
LIST OF TABLES xiv
LIST OF FIGURES xv
LIST OF ABBREVIATIONS xvi
CHAPTERS
1 INTRODUCTION 1
2 PROJECT COMPLEXITY 5
2.1 Definition of Project Complexity 5
2.2 Conceptualization of Complexity 8
2.3 Measurement of Complexity 10
2.4 Management of Complexity 12
2.5 Project Complexity Factors 13
3 MEGA CONSTRUCTION PROJECTS 17
3.1 Definition and Characteristics of Megaproject 17
3.2 Project Complexity in Mega Construction Projects 20
4 RESEARCH OBJECTIVE AND METHODOLOGY 23
4.1 Research Objective and Aims 23
4.2 Research Methodology: Grounded Theory Approach 24
4.2.1 Data Collection 30

5 DATA ANALYSIS 35
5.1 Qualitative Data Analysis 35
5.2 General Information about Coding Procedure 37
5.3 Coding with NVivo 40
6 CASE PROJECTS AND FINDINGS FROM THE INTERVIEWS 51
6.1 Findings from the Interviews 51
6.1.1 Project A 51
6.1.2 Project B 55
6.1.3 Project C 58
6.1.4 Project D 61
6.1.5 Project E 66
6.1.6 Project F 70
6.1.7 Project G 74
6.1.8 Project H 77
6.1.9 Project I 81
6.1.10 Project J 83
6.1.11 Project K 86
6.2 Summary of Findings 89
7 DISCUSSION OF RESEARCH FINDINGS 95
7.1 Complexity Factors 95
7.2 Interrelations between Complexity Factors 103
7.3 Pattern of Complexity 107
7.4 Definition of Complexity in Mega Construction Projects 110
8 SUMMARY OF FINDINGS AND CONCLUSIONS 113

8.1 Summary of Findings 113

8.2 Contributions to Theory and Practice 115

8.3 Limitations of the Research 116

8.4 Recommendations for Future Studies 116

REFERENCES 119

APPENDICES 141

A. Project Complexity Literature Review (Bakhshi et al., 2016) 141

LIST OF TABLES

TABLES

Table 2.1 Project complexity definitions 6

Table 2.2 Project complexity dimensions based on literature review 13

Table 3.1 Cost treshold values of megaprojects (Erol et al., 2018) 19

Table 4.1 Chronology of key methodological texts on grounded theory 26

Table 4.2 Key grounded theory characteristics (Hutchison et al., 2010) 26

Table 4.3 Project details 30

Table 4.4 Expert profile details 31

Table 4.5 Interview details 32

Table 5.1 Steps of coding process 40

Table 6.1 List of higher-level complexity factors 90

Table 6.2 Distribution of coded complexity factors according to the projects 92

Table 7.1 Comparison of findings on the factors that create complexity with the literature 97

Table 7.2 Example quotations about interrelations between the factors 106

LIST OF FIGURES

FIGURES

Figure 4.1 Research process flowchart 28
Figure 5.1 Process used in QSR NVivo software (QSR International, 2021) 36
Figure 5.2 Representation of iterative nature of grounded theory (Hutchison et al., 2010) 40
Figure 5.3 Word cloud analysis for the entire codes 41
Figure 5.4 An example of text search query 42
Figure 5.5 Word cloud analysis for first six project 43
Figure 5.6 Word cloud analysis for each interview 44
Figure 5.7 A sample of coding analysis on the transcriptions in the dataset created with NVivo.. 47
Figure 7.1 Visual representation project complexity and related factors 100
Figure 7.2 Concept map showing structural complexity factors 104
Figure 7.3 Concept map showing emergent complexity factors........................... 105
Figure 7.4 Representation of the pattern of complexity 108
Figure 7.5 An illustration of the dynamic change in complexity 109

LIST OF ABBREVIATIONS

ABBREVIATIONS

BOT : Build-Operate-Transfer

EPC : Engineering Procurement and Contruction

PPP : Public-Private-Partnership

QDA : Qualitative Data Analysis

CHAPTER 1

INTRODUCTION

From a broad perspective, the term “complexity” is defined as “the quality or state of being complex” (Merriam-Webster, 2021). It may be seen that describing the term “complexity” as complex is a tautology. However, this is the problem at the heart of the concept of complexity. Indeed, the underlying view of the early studies of complexity carried out by pioneers of complexity theory from the Sante Fe Institute (Waldrop, 1992; Casti, 1994; Gell-Mann, 1994) is that no single concept of complexity can adequately capture the intuitive notions of what the word ought to mean.

A complex system consists of a number of elements interacting with each other in many different ways (Valle, 2000). The numerous interdependent elements in the complex system continuously interact and spontaneously organize and reorganize themselves into increasingly elaborate structures over time (Dao et al., 2017). Although the exact nature of a complex system is hard to discover due to the large degree to which complex ideas are traded across disciplinary boundaries (Manson, 2001), the same lack of consensus persists even when the term complexity is limited to the project level. While research on the concept of project complexity has been conducted for many years, complexity can be viewed as “the property of a project which makes it difficult to understand, foresee and keep under control its overall behavior, even when given complete information about the project system” (Vidal et al., 2011a). In addition to differentiation and interdependency of complex projects, complexity can be characterized by uncertainty or limited predictability.

Since project complexity is an inherent and indispensable part of a project, it is included in all kinds of projects from simple to mega. Megaprojects, which are commonly defined as large-scale projects with a capital investment of one billion or more US dollars (Flyvbjerg, 2014; Merrow, 2011), are more prominent to deal with project complexity. While the amount of their capital investment often differentiates megaprojects, they are also characterized by being risky, complex, with high uncertainty and significant social impact, as well as engaging many stakeholders (Kardes et al., 2013). Due to its complex dynamics, megaprojects have experienced alarming failure rates in meeting their goals, capital budgets, and/or schedules (Hu et al., 2016; Merrow, 2011; Fiori and Kovaka, 2005). This corresponding problem related to megaprojects' poor performance has been addressed over the years by analysts and scholars. Since they are increasing in numbers and magnitude all over the world, in addition to being applied still with limited experience from the management of complex systems in large scale projects, as a critical project dimension, project complexity provides a basis for determining the appropriate managerial actions required to complete a project successfully. Therefore, a better understanding of megaproject complexity is crucial to ensure their success. In order to increase the understanding and overall performance of the megaprojects, it is necessary to understand and manage the primary source of the problem, and complexity is one of the most critical challenges in the megaprojects which have to be beholden by the researchers (Gransberg et al., 2016). There are extensive research on project complexity; however, researchers had different perspectives on the definition of project complexity (Zhu and Mostafavi, 2017; Dao et al., 2016) and employed different methods (such as Vidal et al., 2011a; Botchkarev and Finnigan, 2015) to assess the project complexity. Although there are various complexity indicators/factors introduced by various authors (Geraldi et al., 2011; Bosch-Rekveldt et al., 2011; He et al., 2015; Vidal et al., 2011b) in the project management domain, many reseachers (such as Xia and Lee 2004; Bakhshi et al. 2016) state the necessity of further research on conceptualizing and assessing complexity. Therefore, the major aim of this thesis is conceptualising complexity in mega construction projects by referring to lived experiences of project managers and identification of key indicators (complexity factors) that can be further used to assess level of complexity in projects. For this purpose, a research study has been designed, and qualitative data has been collected by interviewing 18 participants from 11 mega construction projects.

This thesis is part of a research project (Project No: 217M471) funded by the Scientific and Technological Research Council of Turkey (TUBITAK). The research project aims to develop a visualization tool for risk and complexity in mega construction projects. The aim of the thesis is also to report findings from semi-structured interviews on perceived complexity that constituted the conceptual foundation for the quantitative assessment method for risk and complexity. Also ,the findings on conceptualization of complexity is used to form the basis of the process model and visualization tool. Thus, the thesis aims to understand the project complexity concept, identify dimensions of project complexity, and assess the indicators that genuinely reflect megaprojects' complexity. In this respect, conceptualizing perceived project complexity by exploring lessons learned from actual megaprojects and identifying pattern of complexity constitute the scope of this thesis.

The following content is adopted within this thesis. In Chapter 2, the literature review on project complexity is presented. The definition of project complexity, literature on conceptualization, measurement, and management of complexity are discussed. Also, project complexity factors in the construction industry are revealed. Chapter 3 covers the critical review of previous research on mega construction projects. In this chapter, definition and characteristics of megaproject are discussed, and the place of project complexity in mega construction projects is investigated. Chapter 4 continues with the research objective and aims, and research methodology. In this chapter, research objective and aims, and the steps of data collection are presented. The research methodology is further explained in which a grounded theory approach is utilized to empirically verify the complexity factors and derive a self-explanatory/inclusive definition of perceived complexity. In Chapter 5, data analysis process is explained. In Chapter 6, the case studies and general information about the case studies that were obtained from the analysis are introduced. The Chapter continues with presenting the summary of findings. In Chapter 7, semi-structured interviews' findings are discussed in relation to literature findings, and a new definition of project complexity, actually, "pattern of complexity" is proposed. Finally, Chapter 8 concludes by highlighting the major findings, discussing the research limitations, and making recommendations for future studies.

CHAPTER 2

PROJECT COMPLEXITY

This chapter introduces and details the concept of project complexity from the literature. First, project complexity definitions are explored. Next, to enlighten the concept of project complexity, literature reviews related to conceptualize, measure and manage complexity are investigated. Finally, based on the literature review findings, factors of project complexity are presented.

2.1 Definition of Project Complexity

Although there is various research on the concept of project complexity conducted over the years, researchers have no consensus on what constitutes project complexity. In the literature, project complexity has been defined in various ways (Nguyen et al., 2015; Ahn et al., 2017; Dao et al., 2017), and each researcher had a different perspective, focus on different project features and/or behavior, while defining project complexity (Zhu and Mostafavi, 2017; Dao et al., 2016). To illustrate the variation in definitions suggested by the researchers, fifteen examples highlighting different features of complex projects are quoted in Table 2.1.

The term project complexity is not an easy term and vaguely defined. However, Table 2.1 demonstrates that projects have been considered as complex entities when they have multiple factors interacting with each other in various ways. This makes projects hard to plan, predict, manage and control due to their ambiguity and dynamic structure.

Table 2.1 Project complexity definitions

Reference Study (year)	Definition	Focus
Turner and Cochrane (1993)	Degree of whether the goals and methods of achieving them are well defined	Feature: Uncertainty of goals and methods
Baccarini (1996)	Project complexity consists of many varied interrelated parts and can be operationalized in terms of differentiation and interdependency	Features: Interrelations and interdependency
Maier (1998)	Operational and managerial interdependence of the elements–emergent behavior	Features: Interdependency and emergence
Edmonds (1999)	Complexity is that property of a model, which makes it difficult to formulate its overall behavior	Behaviour: Difficult to formulate/ understand
Tatikonda and Rosenthal (2000)	The nature, quantity, and magnitude of organizational subtasks and subtask interactions posed by the project	Features: Sub-parts and their interactions
Sbragia (2000)	The number of elements in the project, intensity of interactions between elements, and difficulty of cooperation between the functional areas	Feature: Sub-parts and interactions Behaviour: Difficulty of cooperation
Cicmil and Marshall (2005)	Project complexity invokes ambiguity, paradox and the dimensions of time, space and power of the organizing processes in project settings	Behaviour: Ambiguity and dynamic change
Brockmann and Girmscheid (2007)	The complexity is the degree of manifoldness, interrelatedness, and consequential impact of a decision field	Feature: Manifoldness, interrelatedness and interactions
Hass (2009)	Complexity is characterized by a complicated or involved arrangement of many interconnected elements that it is hard to understand or deal with	Feature: Interconnectedness Behaviour: Hard to understand and deal with
Remington et al. (2009)	A complex project demonstrates a number of characteristics to a degree, or level of severity, that makes it difficult to predict project outcomes or manage project	Behaviour: Difficult to predict and manage

Table 2.1 (Cont'd) Project complexity definitions

Reference Study (year)	Definition	Focus
Vidal et al. (2011a)	Project complexity is the property of a project, which makes it difficult to understand, foresee and keep under control its overall behavior, even when given reasonably complete information about the project system	Behaviour: Difficult to understand, foresee, control
Hatch and Cunliffe (2012)	Project complexity consists of many different elements with multiple interactions and feedback loops between elements	Feature: Feedback loops between multiple interrelated elements
Kermanshachi et al. (2016)	Project complexity is the degree of interrelatedness between project attributes and interfaces, and their consequential impact on predictability and functionality	Feature: Interrelations Behaviour : Hard to predict
Bakhshi et al. (2016)	Project complexity is an intricate arrangement of the varied interrelated parts in which the elements can change and evolve constantly with effect on the project objectives	Feature: Interrelations Behaviour: Constant change and evolution affecting objectives
Mikkelsen (2020)	Project complexity is the interrelatedness of elements causing an emergent nature of the project and challenging the project management	Feature: Interrelatedness Behaviour: Emergent and challenging

All definitions bridge over the description of project complexity notion. Considering these definitions regarding to subjectivity of project complexity, interpretation of the project complexity is based on the capability of understanding, explaining, and managing a project (Kiridena and Sense, 2016). Indeed, complexity is needed to be explained from the point of its effect on human cognition (Ahn et al., 2017). Therefore, different individuals might have different complexity perceptions (Jaafari, 2003).

To clarify project complexity, the notion of complexity is analyzed from the 1990s to today. When previous studies on project complexity are considered, most of the studies have been mainly about identification (or categorization) of complexity factors (dimensions) and conceptual models' development to understand complexity. However, researchers have been conducting studies to not only understand and conceptualize but also measure and manage project complexity since the 1990s (Geraldi, 2009). To better understand and conceptualize complexity, publications regarding to complexity theory, project complexity definition and identification, project complexity impacts on project performance, and practices of complexity management are reviewed. Relevant frameworks, models, and tools are also examined for insights. These studies that provide further guidance on describing complexity are investigated, and findings from the literature review are discussed in this chapter's followed sections.

2.2 Conceptualization of Complexity

Studies on the conceptualization of complexity are grouped under two main groups: frameworks developed to determine complexity factors and theoretical models developed to understand complexity. The studies towards developing complexity frameworks and theoretical models usually categorize the complexity factors under certain groups.

In terms of conceptualization of complexity, one of the first attempts was made by Baccarini (1996). He introduced that complexity consists of organizational and technological dimensions. While organizational complexity expressed the excess of organizational structures in the project and the interdependencies of these structures, technological complexity refered to the number and variety of physical work done and the relationships between these works. Williams (1999) gathered two complexity dimensions of Baccarini (1996) into a single dimension as “structural complexity,” which was related to the number of parts and their interdependence. Williams (1999) added uncertainty as another dimension of project complexity by considering uncertainty in goals and methods as complexity drivers. In conceptual model proposed by Cicmil and Marshall (2005) framework to understand the complexity of construction project, social interaction’s complex processes, project performance’s radical unpredictability, performance criteria's persisting ambiguity, conflicting understanding of project success were introduced. Geraldi and Adlbrecht (2007) divided project complexity into three dimensions which were fact, faith, and interaction. Vidal and Marle (2008) examined organizational and technological complexity dimensions defined by Baccarini (1996) and classified them into four subgroups as elements of context, interdependencies within the project system, project system variety, and project system size.

Based on Baccarini's study, Vidal et al. (2011a) identified 18 factors, most of which belong to organizational complexity, using the Delphi method. The TOE framework ("Technical, Organizational and Environmental framework") developed by Bosch-Rekveldt et al. (2011) was one of the most widely known studies in this regard. It combined the findings of the literature with the findings of semi-structured interviews conducted with 18 people from 6 different large engineering projects. The framework included 50 complexity factors under technical, organizational and environmental categories. In parallel, Geraldi et al. (2011) added dynamic, pace, and socio-political dimensions of complexity to Williams's model (1999). Dynamic complexity related to changes in projects including changing specifications or goals. The pace complexity was caused by the urgency to deliver the project. Sociopolitical complexity was related to human-induced communication and interaction issues. In addition to the dimensions expressed by Williams (1999), Dunović et al. (2014) considered constraints arising from goals, resources, and the environment as another important dimension that caused complexity. Botchkarev and Finnigan (2015) considered the complexity with the System of Systems (SoS) approach and defined various project complexity factors under product, project, and external environment systems.

In one of the most comprehensive studies to determine complexity factors, Bakhshi et al. (2016) identified 127 complexity factors under the groups of size, emergence, diversity, connectivity, belonging, autonomy, and context by analyzing 423 articles published in leading project management journals between 1990 and 2015. Relying on the statistical analysis of the survey data collected from 44 projects, Dao et al.

(2017) identified 34 complexity indicators under 11 categories, distinguishing high-complexity projects from low-complexity projects. Montequín (2018) linked complexity to project failure and identify 26 failure (complexity) factors under the headings of “factors related to project,” “factors related to external environment,” “factors related to an organization,” “factors related to the project manager and team members.” Maylor and Turner (2017) modified the framework of Geraldi et al. (2011) by including “pace” into structural complexity, combining “dynamics” and “uncertainty”, and with the combination of them, creating a new dimension named “emergent complexity.” The word emergent was defined by Maylor et al. (2008) as all variability and dynamism, and by Geraldi and Adlbrecht (2007) as the amount and effect of change. Maylor et al. (2008) stated emergent complexity as “a change that occurred over time.” Emergent complexity was also defined as relevant to the concept of “uncertainty,” leading to the “unpredictability” of project outcomes. For example, emergent complexity may stem from changes in scope, emergence of new technology, changes in pace caused by the imposition of a new project deadline, or socio-political changes. When such changes are not well communicated and managed by the team, they may lead to high disorganization, rework, or inefficiency. The fact that projects are changing not only from the “outside-in” but also from the “inside-out” triggers the change in the team motivation or the formation of internal politics (Geraldi et al., 2011).

2.3 Measurement of Complexity

Researchers have developed approaches and proposed models to measure complexity. The complexity perspectives taken into account in these researches help in understanding the complexity. To compute a critical path network’s complexity level, Davies (1973), Kaimann (1974), and Davis (1975) developed a coefficient of network complexity (CNC) (Nguyen et al., 2015). To measure project complexity, Temperley (1982) proposed a measure relying on relationship of activities. Lee and Xia (2002) proposed a measure of information system development (ISD) project complexity with 17 indicators and introduced a two dimensional framework. The proposed software project complexity types were “structural organizational complexity,” “structural Information Technology (IT) complexity,” “dynamic organizational complexity,” and “dynamic IT complexity.”

Nassar and Hegab (2006) proposed a measure to assess the complexity of project schedules based on the connectivity of activities. Hass (2009) developed a project complexity model using systems thinking approach. Xia and Chan (2012) developed a model to calculate complexity for building projects in China. Vidal et al. (2011a) calculated a relative project complexity index between a scale of 0-1 using the Analytic Hierarchy Process (AHP) over the complexity factors they determined. Vidal et al. (2011b) added sensitivity analysis to the previous method and consider the sensitivity of the complexity score to the importance weights of the factors. Gransberg et al. (2013) developed a measurement method named “complexity footprint” that calculates the complexity of transportation projects based on technical, time, monetary, content, and financial dimensions and shows them on radar diagrams. Nguyen et al. (2015) developed a method that measures the complexity level for transportation projects on a scale of 1-10, based on the complexity factors they determined and their importance weights derived from a fuzzy AHP model. A systematic complexity measurement model to evaluate the complexity of mega construction projects with the approach of fuzzy analytic network process (FANP) was proposed by He et al. (2015). A case study of the Shanghai Expo construction was used for illustration of the measurement model and the model including 28 factors of complexity was developed by a Delphi survey. Lu et al. (2015) used the task and organization (TO) perspective to develop a model regarding the measurement of project complexity. In the proposed measurement method, the dynamic “emerging” effect of influencing factors on project complexity aimed to be reflected. Poveda-Bautista et al. (2018) adapted the CIFTER (Crawford-Ishikura Factor Table for Evaluating Roles) method and calculated the complexity score based on 34 complexity factors they determined for information technology projects.

2.4 Management of Complexity

In addition to studies on conceptualization and measurement of complexity, studies also focus on reducing or better managing complexity in the literature. For this purpose, researchers have developed different approaches to manage complexity using different methods. Those methods are mainly based on data analysis, case studies, or theoretical models. To begin with, Cicmil et al. (2009) used project complexity and the classification of complexity in projects in order to define approaches to project complexity in the project management literature. One of the approach as a rationalist approach stated objectifying the project complexity and applying the work of complexity science. Another one, "complexity of," as a subjective approach represented the narrative term "complexity" regarging lived experience of project managers. Koppenjan et al. (2011) developed a framework and practicality of it by implementing the developed framework to the large engineering project in Netherlands. The ability to balance of project managers on management approches related to flexibility and control values was analyzed. They argued that succeeding in accomplishing the balance of "predict-and-control perspective" and "prepare-and-commit perspective" could avoid problems in realizing these complex engineering projects. Davies and Mackenzie (2014) conducted a case study of the London Olympics 2012 construction program and showed that systems integration was one of the significant challenges involved in delivering a complex – "system of systems"– project. They argued that complexity was coped by decomposing a project into different systems and maintaining the integration with interfaces between levels and individual component subsystems. Bjorvatn and Wald (2018) researched the concept of team-level absorptive capacity and studied role of the concept as a mediator between project complexity and project management success. They argued that there was a direct, positive, and unequivocal relationship between project complexity and overspending, and delays. Hu et al. (2018) performed a case study of the Hong Kong-Zhuhai-Macao Bridge project in order to investigate the emergence of institutional complexity and effect of it on project outcomes. They concluded that industrial complexity stem from both macro and micro-level environments; however, complexity from the macro environments was more prone to constraining conflicts in megaproject organizations, whereas micro-actors were more prone to create organizational conflicts.

2.5 Project Complexity Factors

A review of previous studies revealed that project complexity could be characterized by a number of complexity factors. Although analyzed research papers identified overlapping factors related to project complexity, the complexity factors' classifications were not consistent (Nguyen et al., 2015). The various complexity dimensions based on a systematic literature review are shown in Table 2.2.

Table 2.2 Project complexity dimensions based on literature review

Reference Study	Complexity Dimension
Baccarini (1996)	Organisational complexity; Technological complexity
Williams (1999)	Structural complexity; Uncertainty
Girmscheid and Brockmann (2008)	Overall complexity; Task complexity; Social complexity; Cultural complexity
Vidal ve Marle (2008)	Interdependencies within the project system; Project system variety; Project system size; Elements of context
Hertogh and Westerveld (2010)	Technical complexity; Social complexity; Financial complexity, Legal complexity; Organizational complexity; Time complexity
Wood and Ashton (2010)	Uncertainty; Environmental; Operational and technological; Planning and management; Organizational
Bosch-Rekveldt et al. (2011)	Technical complexity; Organizational complexity; Environmental complexity
Geraldi et al. (2011)	Structural complexity; Uncertainty; Dynamic; Pace; Socio-political
Xia and Chan (2012)	Neighboring environment; Geological condition; Project size/scale; Urgency of the project schedule; Construction method; Building function and structure
Dunović et al. (2014)	Structural complexity; Uncertainty; Constraints
Botchkarev and Finnigan (2015)	Product; Project/internal environment; External environment

Table 2.2 (Cont’d) Project complexity dimensions based on literature review

Reference Study	Complexity Dimension
Carvalho et al. (2015)	Financial; Contractual; Technical; Organizational
Lu et al. (2015)	Task complexity; Organizational complexity
Nguyen et al. (2015)	Organizational; Sociopolitical; Environmental; Infrastructural; Technological; Scope
Bakhshi et al. (2016)	Context; Autonomy; Belonging; Connectivity; Diversity; Emergence; Size
Chapman (2016)	Management complexity; Finance complexity; Context complexity; Site complexity; Task complexity; Delivery complexity
Mirza and Ehsan (2016)	Cost complexity; Time complexity; Scope complexity
Luo et al. (2017)	Goal; Organizational; Task; Technological; Environmental; Information complexity
Zhu ve Mostafavi (2017)	Detail complexity; Dynamic complexity
Montequín et al. (2018)	Factors related to external environment; Factors related to project; Factors related to organization; Factors related to the project manager and team members

For instance, Bakhshi et al. (2016) identified one hundred and twenty-eight project complexity factors resulting from the literature review from 1990 to 2015 to explore project complexity's historical development. In the research, complexity factors were grouped into size, emergence, diversity, connectivity, belonging, autonomy, and context dimensions and the related literature review references as shown in APPENDIX A. Although there is no accepted complexity dimension structure in the literature, it seems that almost all complexity factors are mentioned in more than one research. This shows that a level of maturity has been reached regarding what complexity factors are; however, not yet reached in terms of how complexity is conceptualized.

In the study of Bakhshi et al. (2016), it was seen that cultural configuration” and “local laws and regulations” were more reported factors in the project context dimension. Complexity factors such as “cultural variety”, “variety of methods”, “stakeholders’ interests,” “organizational interdependencies,” and “technological skills needed” were high cited factors in the project diversity dimension. The “number of structures, stakeholders, deliverables”, “number of departments involved or method and tools applied”, “largeness of scope”, and “duration of project” were the most popular complexity factors in the size dimension. “Team/partner cooperation and communication”, “interdependencies between objective/interests, sites, departments, and companies” were part of the autonomy dimension, which had been mentioned by researchers more than others. “Goals/interests alignment” and “interconnectivity and feedback loops in the tasks” were the most mentioned complexity factors in the connectivity dimension. And also, “uncertainty of scope, objectives, and methods”, “technological newness of the project”, and “trust in stakeholders” were more cited in the emergence and belonging dimensions. Last but not least, project diversity and size dimensions consist of many factors cited by more than one-third of researchers. For this reason, it is beneficial to conduct case studies with megaprojects involving a high level of project diversity and size-related factors to conceptualize and define complexity.

Moreover, Whitty and Maylor (2009) state that structural, dynamic, and interaction elements are included in a high level of project complexity. In parallel with Whitty and Maylor’s statement, description of Cicmil et al. (2006) regarding complexity in projects is related to structural elements, dynamic elements, and their interaction. There is an agreement between researchers on static factors leading to project complexity as well as some factors that change over time (scope, relations etc.) and also on level of complexity changing over time due to evolving interrelations between emergent and static factors. Based on this idea, Geraldi et al. (2011) argued that the understanding pattern of complexity would give a more informed approach to studying complexity of projects. Built on previous findings on project complexity, in this research, understanding perceived complexity in mega construction projects and identifying pattern of complexity that could further be used to assess level of complexity are aimed. Why megaprojects are chosen as the scope of this study and their characteristics are discussed in the next chapter.

CHAPTER 3

MEGA CONSTRUCTION PROJECTS

This chapter introduces the concept of megaproject and discusses the characteristics of megaprojects from the literature. First, to capture the reason why specifically project complexity in megaprojects need to be explored, megaprojects definitions and characteristics of megaprojects are explored. Next, project complexity in mega construction projects are investigated to understand the collective understanding of project complexity.

3.1 Definition and Characteristics of Megaproject

A project form diversely described as a megaproject is increasing popularity in recent years (van Marrewijk et al., 2008; Flyvbjerg et al., 2003). In recent years, the popular project form, megaprojects, is commonly defined as large-scale, complex projects that typically cost one billion or more U.S. dollars (Flyvbjerg, 2017; Merrow, 2011). Capka (2004) described "megaprojects as multimillion-dollar projects requiring the management of numerous, concurrent, and complex activities constrained by aggressive delivery schedules and fixed budgets." While their capital investment often differentiates megaprojects, they are also characterized in different ways. For instance, Zhai et al. (2009) stated characteristics of megaprojects as "extreme complexity, substantial risks, long duration and extensive impact on the community, economy, technological development, and environment of the region or even the whole country." Haidar and Ellis (2010) proposed that megaprojects' definition is based on the combination of size and complexity. Van Marrewijk (2007) defined megaprojects as including high-risk technical innovation, high potential for ambiguity, and conflict between stakeholders. Fiori and Kovaka (2005) identified a megaproject as a single or combined project formed by high cost, high-level risk, extreme complexity, high impact on the society, and many other challenges to the stakeholders. Zidane et al. (2012) defined megaproject as “giant scale, the average capital cost of 985 million U.S. dollars, long duration, technological demand and organization of different disciplines”. Accordingly, all megaproject-related definitions lead one to infer that there is no uniformly accepted definition for the term “megaproject” other than large, expensive, and complex.

As it is seen in the definitions, some characteristics enable the definition and categorization of megaprojects. In general, they can be examined under the main features like size, budget, duration, impact, uniqueness, and complexity. For the megaprojects, size, large scale, and giant size are the most used terminologies (Flybjerg, 2014; Zidane et al., 2012). Although megaprojects are high-cost investments that typically cost one billion or more U.S. dollars, the definition of cost threshold as “one billion or more U.S. dollars” varies between emerging and developed countries (Erol et al., 2018). Therefore, there are several definitions of the cost threshold value in terms of local currency or a ratio that shows the relationship between total project cost and Gross Domestic Product (GDP) of the country, as demonstrated in Table 3.1.

Megaprojects are also characterized as investments with long construction periods (Brockman and Girmscheid, 2007). Enormous resources, including human, technological, and financial resources, are used over a long duration (Capka, 2004). The uniqueness and originality of megaprojects is another aspect mentioned in the literature. Some examined the megaproject examination in terms of technological aspect (Boateng, 2014), while some associated the uniqueness of megaprojects with a combination of strategic, operational, time, cost, quality, human resources related parameters (Zidane et al., 2012). Due to their structure including large-scale, high cost, and long-term, megaprojects can create substantial direct and indirect effects on state, environment, and stakeholders (Zidane et al., 2012; Mišić and Radujković, 2015). Furthermore, since they can be regarded as modern symbols of prestige and political power (Van Marrewijk, 2017), successful megaprojects contribute to the local and national economy by creating employment opportunities and affecting other industries' improvement (Ma et al., 2017). Another critical characteristic is complexity which dominates the entire structure of the megaproject. This is because, megaprojects are highly complex investments since it includes complex interrelations among different elements of the project (Brockmann and Girmsheid, 2007), interfaces and interdependencies between the project owner, government, sponsors, contractors, consultants, suppliers, community, and other hidden stakeholders (Wu et al., 2018) as well as cutting-edge engineering and technology (Kardes et al., 2013).

Table 3.1 Cost treshold values of megaprojects (Erol et al., 2018)

Reference Study	Cost Threshold
Kumaraswamy (1997), Capka (2004), Han et al. (2009), Jergeas and Ruwanpura (2010), Rolstadås et al. (2014), Flyvbjerg (2014)	1 billion US Dollar
Hu et al. (2015a)	5 billion Chinese Yuan ~ 734 million US Dollar (National Development and Reform Commission in China)
Hu et al. (2015a), Biesenthal et al. (2018)	0.5-1 billion US Dollar
Eweje et al. (2012)	0.3-20 billion US Dollar
Mišić and Radujković (2015)	250-300 million Euro (for small and medium sized European countries)
Hu et al. (2015a)	100 million Euro (International Project Management Association-European Union)
Mok et al. (2015)	1 billion HK Dollar ~ 127 million US Dollar (Development Bureau in Hong Kong)
Brookes and Locatelli (2015)	100 million US Dollar
Hu et al. (2015a)	United States: 0.01% of GDP EU Countries: 0.02% of GDP China: 0.01% of GDP Hong Kong: 0.01% of GDP South Korea: 0.05% of GDP

Characteristics of a megaproject described above demonstrate the complicated nature of the megaprojects. Due to the nature of the megaproject, it includes high levels of challenges such as the necessity of making decisions under the conditions of uncertainty and risk (Atkinson et al., 2006) and the potential for important conflicts of interest between the stakeholders in the public and private sector (Alderman et al., 2005; Clegg et al., 2002). There are also concrete examples in the literature that these difficulties have a significant impact on project performance as causing considerable cost overruns, delay in completion of the project, and failure to deliver against the objectives used to justify projects (Miller and Lessard, 2000; Flyvbjerg et al., 2003; Williams, 2005; Flyvbjerg, 2009). While a considerable number of large and complex projects are constructed within an acceptable scope, budget, and time parameter, lots of megaprojects, specifically the ones having innovative technological applications, frequently fail in one or more success dimensions (Hartman and Ashrafi, 2004). In that respect, there is a consensus on the poor performance of megaprojects among scholars. Therefore, there is a need for special attention to understanding the dynamic, complex, and risky nature of megaprojects. Since complexity is a prominent part of a megaproject and the inexplicable concept of complexity affects understanding and managing megaprojects, it requires a closer examination of the concept of complexity in the megaproject.

3.2 Project Complexity in Mega Construction Projects

There is a consensus among researchers that complexity is a common characteristic of megaprojects (Capka, 2004; van Marrewijk and Smits, 2016; Pitsis et al., 2018). The complexity of megaprojects root in several contributing factors such as personnel, components, tasks, and budget, as well as a great number of uncertainties and their interactions (Mihm et al., 2003; Sommer and Loch, 2004). The main factors leading to project complexity contain large scale, long period, escalating costs over time, the number of participants, diversity of technological disciplines, stakeholders' interests, multi-nationality, sponsor interest, high levels of public attention or political interest, uncertainty, and country risk (van Marrewijk et al., 2008).

The large scale and scope of megaprojects are one of the reasons for complexity. Since the duration of megaproject construction from initiation to completion can take many years, several changes regarding economic and political situation and laws, and regulations may occur during the period of the project (Kolltveit and Grønhaug, 2004). Since numerous factors possibly influence a particular cause of action, evaluation of the cause-effect relationships and the project performance are also challenging (Flyvbjerg, 2017). The existence of great numbers of different and interconnected activities is contributing to complexity. Besides, megaprojects mostly constructed on an innovative technology and out of spec design, which makes it challenging to learn from experience (Prencipe and Tell, 2001). Since the technology used is often new, its behavior and functionality aren't mostly easy to foresee. With diverse and conflicting institutional backgrounds, megaprojects involve multi-actor processes. Establisment of governance and management mechanisms across cultures of institutions is generally difficult (Levitt and Scott, 2017). The number of project participants, including contractors, governments, sponsors, sub-contractors, funding agencies, investors, and suppliers, leads to increase in the project complexity. Moreover, due to competing characteristics and aims of stakeholders, it is not easy to maintain each stakeholder's interests and find common ground for many stakeholders. Moreover, since megaprojects often include large amounts of resources due to their nature, resource management often creates complexity. Finally, megaprojects are often built on insufficient data about schedules, costs, and risks. Therefore, they often lead to cost overruns, delays, and shortfalls that weaken project applicability during delivery of the project (Flyvbjerg, 2017). Those difficulties need to be solved while "flying the plane," tending to lead to challenges during implementation. It is a fundamental management problem that causes complexity and mostly leads to megaprojects' failure (Merrow, 2011).

Literature review findings point out that complexity as a common characteristic of megaprojects shall be conceptualized, and then management strategies are formulated to ensure project success. Although the contribution to to developing the collective understanding of project complexity, the extant literature on the characteristics and differences of megaprojects from the other projects raises the need to explore the project complexity concept specifically for megaprojects (Ma and Fu, 2020). Besides the lack of dedicated project complexity understanding for megaprojects, there is an increasing tendency towards megaprojects, raising a need to examine better the complexity notion in megaprojects' structures and dynamics. In the next chapter, the major gap on perceived complexity in mega construction projects and the proposed methodology for exploring the perceived complexity is presented.

CHAPTER 4

RESEARCH OBJECTIVE AND METHODOLOGY

This chapter introduces the knowledge gaps on perceived project complexity understanding for mega construction projects. Then, a grounded theory approach as research methodology and collection of data are introduced to explore perceived complexity by lived experiences of project managers.

4.1 Research Objective and Aims

The literature review has revealed that megaprojects' characteristic features make it necessary to develop a complexity understanding exclusive to them. In despite of the a great amount of existing studies regarding the project complexity understanding, there is still a lack of perceived project complexity understanding for megaprojects in the construction sector. In this respect, in the light of the findings from the in-depth literature review, knowledge gaps that need to be addressed have been identified as follows:

1. Although extensive research on complexity in projects exists, there isn’t any conceptual definition agreed upon among researchers. Each researcher had a different perspective on the project complexity definition (Zhu and Mostafavi, 2017; Dao et al., 2016). The necessity of further research on examining complexity from diverse perspectives in the project management literature has also been mentioned by several researchers (such as Bakhshi et al., 2016).
2. The understanding pattern of complexity gives a more informed approach to research complexity of projects (Geraldi et al., 2011) and be further used to assess the level of complexity. There is a necessity to explore perceived

complexity in mega construction projects by lived experiences of project managers and derive a self-explanatory/inclusive definition of perceived complexity.

3. Although various complexity factors were proposed by various different authors (Vidal et al., 2011b; Geraldi et al., 2011; Bosch-Rekveldt et al. 2011; He et al., 2015), not having a commonly agreed definition or scope leads to studies on defining and identifying the factors of project complexity in general; however, making sense of complexity requires in-depth qualitative analysis, explicitly focusing on megaprojects. Hence, there is a need to synthesize these indicators and empirically verify the complexity factors.

Consequently, this research aims to understand perceived complexity in mega construction projects and explore the pattern of complexity that makes a mega construction project complex.

4.2 Research Methodology: Grounded Theory Approach

Since the study seeks to generate a detailed description of complexity in mega construction projects, an inductive qualitative research strategy based on the grounded theory approach was utilized. The grounded theory methodology, first proposed by two sociologist Anselm L. Strauss and Barney G. Glaser, was defined as "the theory that was derived from data, systematically gathered and analyzed through the research process; in this method, data collection, analysis, and conclusive theory stand in close relationship to one another" (Strauss and Corbin, 1990). The philosophy of grounded theory is based on symbolic interactionism. It assumes that meaning is socially constructed, negotiated, and changes over time through reflexive interaction of individuals (Charmaz, 2000; Goulding, 2005; Mansourian, 2006).

After the classic grounded theory research method was originated in the 1960s by Glaser and Strauss (1967), its initial development was diversified. According to the classical grounded theory, concepts and conceptual relationships are abstracted from data rather than revealing testable hypotheses from existing theories. After a time, the originators of grounded theory came to disagree about the method’s fundamental features. These debates had emerged regarding how best to achieve grounded theory, and some quality control-related issues had been raised (Strauss, 1987; Glaser, 1998, 2005; Strauss and Corbin, 1990). Both Glaser and Strauss modified the approach (Strauss and Corbin, 1990; Glaser, 1978). In general, the main divergences between the Glaserian and Straussian schools of grounded theory was in their methodological procedures for coding data and developing categories, memoing and sampling, the distance of researcher, and theory development (Mansourian, 2006; Jones and Noble, 2007). Glaser emphasized induction only as the core of the approach (Glaser and Strauss, 1967). Based on his ideology, researchers should avoid any literature review regarding to the subject being under investigation and have almost no prior perception in mind of the researcher until after the interviews are completed and initial coding of the data is done (Glaser, 1998; Locke, 2001). On the other hand, Strauss more focused on systematic procedures and validation. His version stresses that induction, deduction, and verification are fundamental (Corbin and Strauss, 2014). Later on, many researchers adapted grounded theory for the usage of various philosophical areas such as postmodernism, feminism, and constructivism (Mills et al., 2006). The most modern versions of grounded theory preferred building their methodological structure on Strauss instead of Glaser, such as “Constructivist Grounded Theory.” In this approach, Bryant (2002), Charmaz (2006), and Bryant and Charmaz (2007) highlighted the importance of coproduction during the construction of concepts and their interpretations by researchers and participants. These different approaches that reflect different epistemological and theoretical perspectives on grounded theory are given as a chronological alignment in Table 4.1.

Despite the different perspectives to grounded theory, several characteristics that symbolize the underlying principles of the methodology have been featured by all of the originators. Key grounded theory characteristics are given in Table 4.2.

Table 4.1 Chronology of key methodological texts on grounded theory

Reference Study	Key Methodological Texts on Grounded Theory
Glaser and Strauss (1967)	The Discovery of Grounded Theory Strategies for Qualitative Research
Glaser (1978)	Advances in the Methodology of Grounded Theory, Theoretical Sensitivity
Strauss (1987)	Qualitative Analysis for Social Scientists
Strauss and Corbin (1990)	Basics of Qualitative Research Grounded Theory Procedures and Techniques
Glaser (1992)	Emerging Versus Forcing Basics of Grounded Theory Analysis
Charmaz (2000)	Objectivist Versus Constructivist Grounded Theory
Glaser (2002)	Constructivist Grounded Theory?
Charmaz (2006)	Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis

Table 4.2 Key grounded theory characteristics (Hutchison et al., 2010)

Characteristics	Details
An iterative process	Due to the necessity of concurrency in data collection and analysis, collection and analyses of data enlighten the subsequent sampling and analytical procedures. Indeed, the process helps to create emergent possibilities.
Sampling aimed at theory generation	Theoretical sampling are related with research question and the theory development process of grounded theory research.
Creating analytical codes and categories	During the data analyzing process, concepts and their properties are defined in the data. The analytical codes and categories are needed to be cover the significant part of data itself.
Advancing theoretical development throughout	Depend on the researcher's theoretical stance, a set of techniques might be adapted to improve development of the theory.
Making systematic comparisons	Constant comparisons at every phase of the data analysis defines variations in the patterns to be found in the data and used for developing distinctions.
Theoretical density	When new data reveals no new and additional theoretical insights, it is accepted that theoretical saturation is reached. Theoretical density regarding data analysis results with theory development.

Although the core grounded theory characteristics are persistent for all research domains, researches in the management domain needs more formal and step-by-step procedures to generate theory from empirical data rather than producing results by trusting in an uncertain process inherent in pure grounded theory (Locke, 2001). Although Corbin and Strauss (2015) state a general grounded theory process that can fit qualitative researches in almost all social science disciplines, for researches in different disciplines and accommodate their research requirements, remodeling the grounded theory approach might be a necessity (Goulding, 2005; Fendt and Sachs, 2007). Even if the approach is remodeled, the general theoretical principles of grounded theory need to be preserved. For this reason, in this study, the variant of the grounded theory approach proposed by Strauss and Corbin (1990, 1998) is used with minor modifications.

Strauss and Corbin recommend additional procedures and techniques in the grounded theory approach, including "constant comparative" techniques and matrices in analysis for improving grounded theory studies' quality. They propose three levels of coding named as open coding, axial coding, and selective coding. Open coding is "the process of breaking down, examining, comparing, conceptualizing, and categorizing data," while axial coding investigates the relationship between categories of the searched subject in the data according to "who, when, where, why, how, and with what consequences?" (Strauss and Corbin, 1998). Selective coding's purpose of which is to identify the core category systematically relating it to other categories: "the central phenomenon around which all other categories are integrated" (Strauss and Corbin, 1990). Furthermore, in the methodology proposed by Strauss and Corbin, theoretical memos are used throughout the process to follow the analysis and guide when needed. The use of literature to research with prior knowledge and enhance the research's theoretical sensitivity is also allowed in the grounded theory developed by Strauss and Corbin.

Since the grounded theory approach aims to construct a data-driven theory (Glaser and Strauss, 1967; Glaser, 1978, 1992; Strauss, 1987), this research's methodology is mainly based on data collection and analysis. Theory development proceeds concurrently with the data collection and analysis processes. Figure 4.1 shows the process of the proposed grounded theory research methodology.

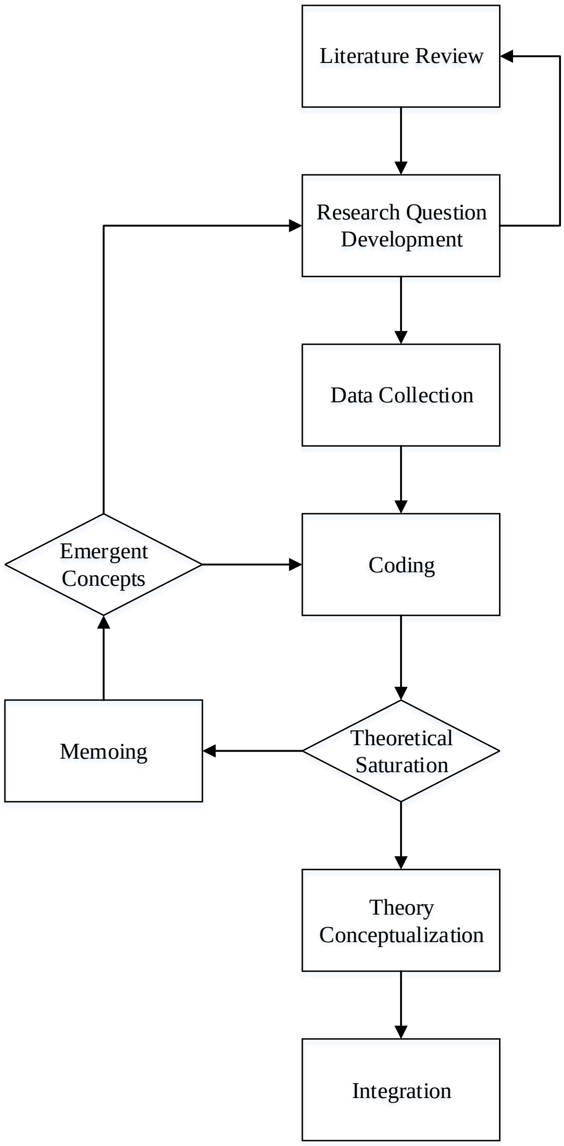

Figure 4.1 Research process flowchart

The methodology consists of three main processes: familiarity with concepts, data collection and analysis, and theoretical grounding. In the process of familiarity with concepts, a literature review of the phenomenon was conducted as an initial step. Since familiarity with concepts was an iterative process, exploring the research question was associated with the literature review related to the phenomenon under investigation. The literature review outputs were processed to be the input of the research questions, and by the direction of the iterative literature review, initial interview questions were formulated. Since the grounded theory has interrelated processes for data collection and analysis, the second process represented the iterative data collection and data analysis process. Although research data may come from several different sources, including videos, images, text, interviews, observations, in this research, data collection data was done with the help of interviews and observations.

The grounded theory demands that data collection and analysis occur simultaneously rather than in a linear sequence, usually in different research strategies (Dunne, 2011). Thus, there was a concurrency between the transcription of interview data and the data analysis process. Transcription to text format and interviews' analysis began immediately after completing each interview to identify concepts and categories effectively. The process of data collection and analysis was a dynamic process that includes, in a sense, an iterative relationship of data collection, open coding, selective coding, and memoing process. The memoing process as theorizing write-up ideas about codes was connected with coding since there was a constant interaction between memos and the concepts in coding at each stage of the analysis from the first coding session towards the end of the analysis. The back loop to the formulation of interview questions showed the readjustment of interview questions to add emerging issues into the next interview. The theoretical saturation of categories indicated that consistency and representativeness were achieved. Then, the theoretical grounding process started, in which reformed theory during the data analysis was generalized. There were three main stages of theory generation: selective coding, theory contextualization, and integration. In selective coding, emerging concepts, categories, and the relationships among them were grounded. The last two, contextualizing the theory and integration, were fundamentally connected with refinement of the theory and modification within the research context.

4.2.1 Data Collection

The methodology pursued started with an in-depth project complexity literature review, including a critical research on existing conceptualizations, theoretical models, and complexity frameworks. To understand perceived complexity in mega construction projects and explore the pattern of complexity that makes a mega construction project complex, first, insights were drawn from a literature review related to complexity. The review process followed an approach similar to the by Geraldi et al. (2011)'s adopted process. However, as different from the study of Geraldi et al., a greater emphasis was put on the definitions, conceptualizations, and project complexity frameworks.

After an in-depth review, the interview structure was designed, and projects suitable for this research were explored using press releases, public documents, company reports, and other internet sources. Then, companies involved in these projects were contacted by email, including a brief outline of the research, to request their participation. As a result of this process, 18 participants from 11 mega construction projects agreed to supply data. Details related to the projects, expert profiles, and interviewees are given in Table 4.3, Table 4.4, and Table 4.5, respectively. Since interviewees were assured of confidentiality, they were assigned unique interviewee numbers, and the name of the project was symbolized with a letter.

Table 4.3 Project details

Interview Number	Project Name	Project Type	Cost ($ Billion)	Start Year	Project Status
Interview 1	A	Power Plant	0.782	2016	Under construction
Interview 2	B	Metro	1.200	2008	Completed
Interview 3	C	Hospital	0.600	2015	Completed
Interview 4	D	Hospital	0.300	2013	Under construction
Interview 5	E	Pipeline	0.413	2016	Completed
Interview 6	F	Hospital	0.290	2014	Under construction

Table 4.3 (Cont'd) Project details

Interview Number	Project Name	Project Type	Cost ($ Billion)	Start Year	Project Status
Interview 7	G	Airport	0.275	2014	Completed
Interview 8	H	Pipeline	1.788	2002	Completed
Interview 9	I	Railway	3.600	2004	Completed
Interview 10	J	Highway	7.500	2013	Completed
Interview 11	K	Power Plant	0.632	2014	Completed

For validity and reliability of the research data, it was aimed to select different types of projects. However, since the cost is a decisive feature for megaprojects, the primary criterion for selecting the projects was their cost. Although the researchers suggest different values, the cost threshold was selected as 0.02% of Gross Domestic Product (GDP), as suggested by Hu et al. (2015). On the other hand, the interviewees' criterion was determined as having experience in complex projects and working at the management levels in mega construction projects. While identifying the target participants for the interviews, criterion sampling was applied, where all cases meet some criteria. The aim of selecting participants by criterion sampling was to ensure that a realistically achievable amount of interviews can be conducted with a broader community representative.

Table 4.4 Expert profile details

Category	Item	Number of Participant
Gender	Female	15
	Male	3
Education background	B.Sc.	4
	M.Sc.	13
	Ph.D.	1
Years of experience	6–15 years	7
	16–25 years	7
	26–35 years	4
Megaproject experience	Medium	3
	High	9
	Very High	6

The list of the main questions asked in the narrative interviews are as follows:

Q1. Could you briefly explain the scope of the project?

Q2. Can you call this project a complex project? If your answer is yes, what are your main reasons for naming it as complex?

Q3. Can you please give some examples about sources/events/factors that made your project complex?

Table 4.5 Interview details

Interview Number	Interviewee Number	Position	Experience of the respondent (years)	Interview Duration
Interview 1	Int. 1, Int. 2	Contract Manager & Lead Planning Engineer	13 and 11	48 min.
Interview 2	Int. 3	Project Coordinator	13	58 min.
Interview 3	Int. 4, Int. 5	General Coordinator & Technical Manager	32 and 15	1 hr. 32 min.
Interview 4	Int. 6	Technical Office and Contracts Manager	20	1 hr. 46 min.
Interview 5	Int. 7, Int. 8	Planning and Contracts Manager & Technical Manager	15 and 23	2 hr. 24 min.
Interview 6	Int. 9, Int. 10	Technical Office Manager & Project Controls Manager	22 and 14	4 hr. 3 min
Interview 7	Int. 11, Int. 12	Deputy General Manager & Project Finance and Business Development Executive	31 and 8	1 hr. 5 min.
Interview 8	Int. 13	Head of Project Controls	25	1 hr. 59 min.
Interview 9	Int. 14, Int. 15	Deputy Project Manager & Construction Manager	33 and 18	1 hr. 49 min
Interview 10	Int. 16, Int. 17	Technical Coordinator & Construction Manager	22 and 37	1 hr. 11 min
Interview 11	Int. 18	Project Director	17	1 hr. 1 min

This research is a part of a funded research project that aims to develop a visualization tool for risk and complexity in mega construction projects. The initial step of the research project was a qualitative analysis of semi-structured interviews to conceptualize complexity. However, in the interview, empirical data had also been collected to analyze the relationship between risk and complexity in mega construction projects (Erol et al., 2020). For this reason, the interviews included questions based on both complexity and the relation between risk and complexity. Although semi-structured interviews were prepared in the scope of the research project, in this research, exclusively the part of the interview related to complexity is mentioned, and this part of the interview is called as narrative interview.

Since the research methodology was based on the grounded theory approach, questions of the interviews were designed as open-ended to encourage free discussion. The main focus was to get the interviewees to talk about their experiences in handling different issues for megaprojects they are involved in. Each interview was conducted with a framework of common questions reflecting on the phenomena under investigation. During the interviews, further questions were asked based on the responses received to clarify the subjects. The following questions can be given as further questions to encourage discussion: “What are the project features that make this project original?”, “Can you evaluate the impact of the factors we discussed earlier on project complexity?”, “Did the complexity factors you mentioned have an impact on other factors?”, “Should we evaluate the complexity you are talking about on an individual factor or on the combination of more than one factor?”, “What could be done to reduce or better manage the complexity of the project?”, and “How do you evaluate the duration, budget and quality performance of the project? If so, what are the root causes of disagreements and performance problems? Can you give examples of the effects of complexity factors on project performance?”. Moreover, since the theory-building approach of grounded theory is based on an iterative data collection and analysis throughout the research process (Strauss and Corbin, 1998), new interview questions evolved with the refinement of the concepts during the analysis of the previous interviews. In the following chapter, details of qualitative data analysis are presented.

CHAPTER 5

DATA ANALYSIS

This chapter introduces the qualitative data analysis (QDA) of data gathered from semi-structured interviews. General information about qualitative coding prosedure based on grounded theory approach are presented. Finally, steps of coding with QDA software are explained.

5.1 Qualitative Data Analysis

Qualitative data is described as soft data. In this sense, QDA is characterized by the usually narrative analysis, which focusing on the meanings to get identity about particular elements of the qualitative data set (Stratigea et al., 2012). Since the aim is to transform raw data into a set of findings, researchers use it to make sense of the data they have collected. Accordingly, the process is essentially about detection using "defining, categorizing, theorizing, explaining, exploring and mapping" (Ritchie and Spencer, 2002). The findings arise through an analysis process that is in the direction of induction rather than deduction. Therefore, although there are many other QDA types, it is most commonly associated with the grounded theory approach (Corbin and Strauss, 2014).

Since QDA includes sorting and categorizing notes and interview transcripts systematically, advances in computer technology assist with analyzing qualitative data. Although a set of software packages is developed to use for QDA, the impact of software on method enables a number of debates (e.g., Hutchison et al., 2010; Weitzman, 2000). These concerns include the applicability of any complicated analysis without completely understanding the techniques' principles and neglecting the human interpretation and reflection role. On the other hand, if appropriately used, enhancing the data analysis process's efficiency using computers for recording, sorting, matching, and linking is generally accepted (Hutchison et al., 2010).

In this research, the data analysis was carried out using the latest version (Version 12) of the QSR NVivo QDA software to organize and assist with analyzing interview transcriptions. The NVivo software helps the analysis move beyond the description of the studied phenomena to an explanatory theory grounded in the data (Hutchison et al., 2010). The methodological approach used in QSR NVivo software is given in Figure 5.1.

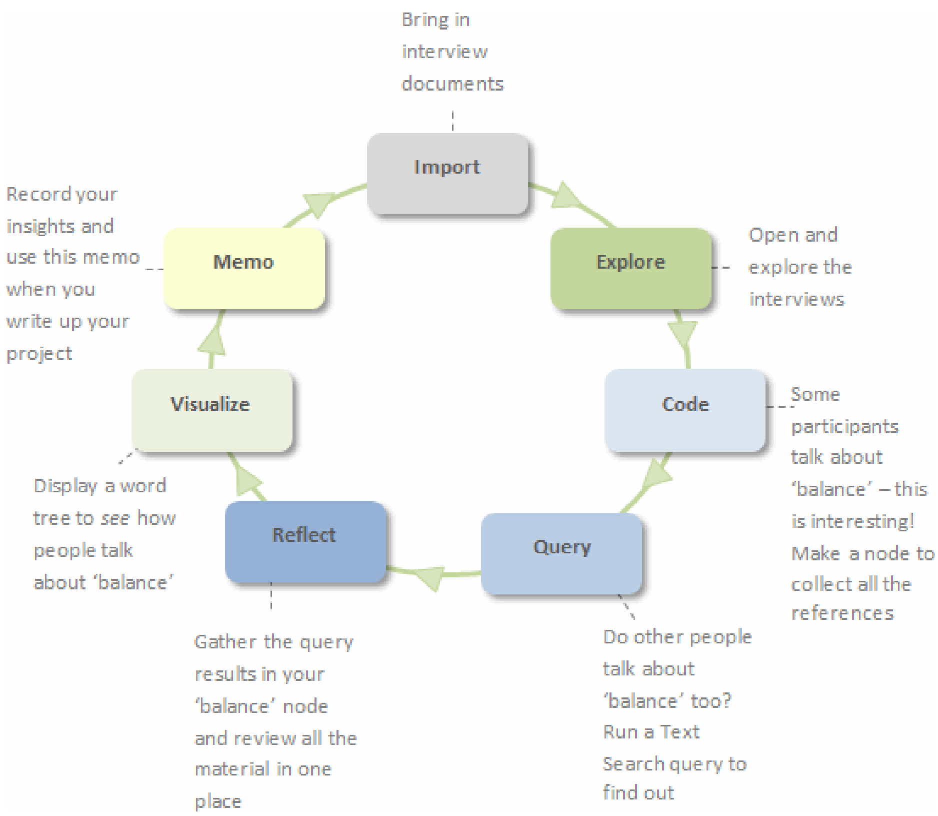

Figure 5.1 Process used in QSR NVivo software (QSR International, 2021)

The progressive iterative process starts with importing raw data into NVivo software for exploring the hidden meanings in the raw data. To explore data, a coding procedure is used, which is a way of generating new thinking about data and promoting reflection and ideas grounded in the data. It is used “to expand, transform, and reconceptualize data” (Coffey and Atkinson, 1996). When codes are combined with queries and visualizations, new insights are encountered and noted in NVivo software as memos. After that, the next iterative process is started with the findings obtained from these memos and codes. The given iterative process associated with grounded theory facilitated by NVivo provides transparency which enhances study reliability and validity (Bringer et al., 2004).

5.2 General Information about Coding Procedure

Coding is naming data segments with a label, which at the same time summarizes, categorizes, and represents each piece of data (Charmaz, 2006) and it is the essential bridge between collection of data and development of an emergent theory to explain these data. Therefore, the logic in the grounded theory coding is different from quantitative logic in which preconceived categories apply to the data. In grounded theory, codes emerge during data scrutinization. Through the coding, interaction with participants and subsequently interact with them again many times over through studying their statements and observed actions. The actions and views of the participants from their perspectives are understood. It is misleading and problematic since these perspectives mostly assume much more than what is apparent. As a result, a flexible procedure needs to be followed to capture the core meaning accurately.

As the requirement of grounded theory regarding simultaneous data collection and analysis, transcription to text format and analysis of the interviews begin immediately after completion of each interview to effectively analyze the data. This analysis process includes three-level coding procedures named open, axial, and selective coding with NVivo. Although Strauss and Corbin provide a detailed set of steps involving three major states for coding that follows their inductive approach, in all three models introduced by Strauss and Corbin, Glaser and Strauss, and Charmaz coding begins by describing small parts of the data: paragraphs, sentences, and even lines or words. This process is iterative, consisting of reading, re-reading, and categorizing data in “every way possible” (Glaser, 1978) and named open coding as it involves the initial conceptualization of data. The term “open coding” refers to the process where the transcribed interview data is opened up to expose the thoughts, ideas, and meanings to uncover and naming the concepts for which the interviewee may not have been consciously unaware (Corbin and Strauss, 2014). Open coding was used to open the data and to see nuances in it. Besides enabling to have a clear look at what participants say and, likely, struggle with, this type of coding helped to identify implicit concerns as well as explicit statements. Since open coding is able to create a set of ideas and information, it enables to discover ideas on which could be built. Therefore, open coding involves the initial conceptualization of data.

During open coding, after the transcribed data are broken into small parts (term, phrase, and sentence), they are carefully analyzed and compared to other parts to catch certain differences and similarities (Corbin and Strauss, 2014). Each part is named in order to represent its underlying concept. As the data analysis is proceeding, any newly identified concepts from subsequent interviews are compared to those already coded. If they shared similar characteristics, the same code is assigned to that concept. If else, a new code is created. Since the data analysis process is iterative, many categories are identified after the first interview transcription. The number of new categories starts to decrease gradually as some concepts are repeated in the interviews. Furthermore, while reviewing the transcribed data, extensive memos that lead to identifying, naming, and describing the emerging concepts and categories are also created. It is noted down to reflect the perceived meaning of what the respondent indicates in the conducted interviews. As a result, a list of categories is identified, summarizing the key concepts found in the interviews.

After identifying the emerging concepts and categories, the axial coding process is initiated to refine the list by deleting or combining some of the categories. Strauss (1987) views axial coding as building a dense texture of relationships around the "axis" of a category. This process is named “axial coding” because it is undertaken around the axis of a category and linking categories under their core meanings

(Corbin and Strauss, 2014). The axial coding specifies the properties and dimensions of a category, and the purpose of this process is to sort, synthesize, and organize large amounts of data and reassemble them in new ways after open coding (Creswell, 1998). In this sense, axial coding is used to bring data that separated pieces and distinct codes back together again in a coherent whole. This process converted categories into concepts, in other words, dimensions of a larger category.

The open codes are grouped into meaningful categories to understand higher-level categories. Moreover, data fragmented with open coding are rebuilt and rearranged by establishing new relationships between categories and their subcategories (Strauss, 1987). This process significantly helps to form more precise and complete understanding about the particular phenomena. Identification of the emerging connections between categories and subcategories is made through constant comparisons of data. The axial and open coding proceeds together naturally until each category reaches a saturation level since saturation is more a matter of reaching the point where any new concepts let to extend the scope of the research rather than adding into the existing categories. With achieving each category's theoretical saturation with the help of constant comparisons, emerging relationships are validated. After that, the structure of axial coding is developed.

Once the main categories and connections are identified, they are integrated to form a broader theoretical framework to complete data analysis. As a final stage, integration and development of categories towards forming a theory are named selective coding. Thereby, after selective coding, the research findings can convey what the research is about. Through this process, the theory's generalization begins, and an explanation of the interrelations and interdependencies between concepts and categories is empirically formed. In this sense, the main idea is to obtain an overall picture that clarifies the investigated subject. The representative example of grounded theory study to demonstrate the iterative nature of coding procedure is given in Figure 5.2.

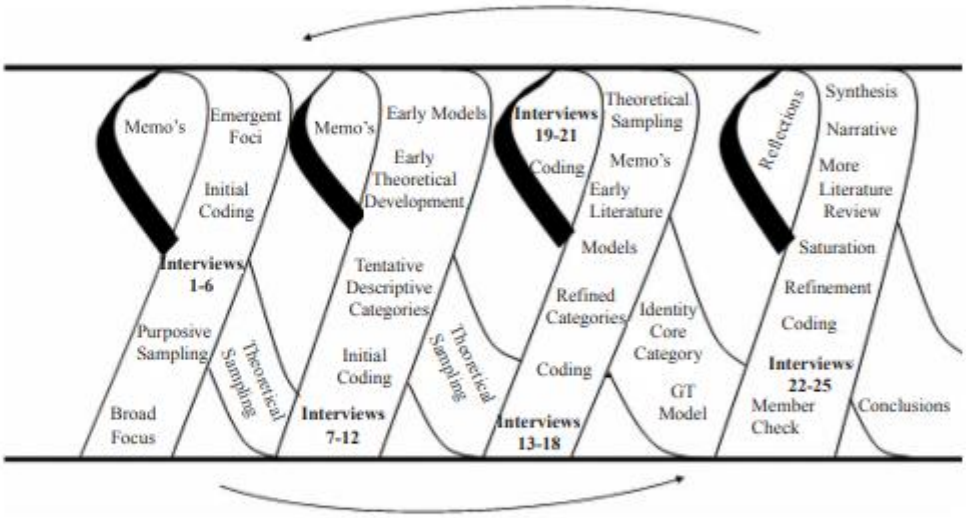

Figure 5.2 Representation of iterative nature of grounded theory (Hutchison et al., 2010)

5.3 Coding with NVivo

In this section, coding with QDA software, NVivo, are explained step by step. For the integrity of steps, the relationships between processes and steps are shown in Table 5.1.

Table 5.1 Steps of coding process

Process	Steps
Making the Text Manageable	Determination of potential topics
	Textual Coding
	Open/Initial coding
Hearing What was Said	Axial Coding
Developing Theory	Selective Coding
Theory Conceptualization and Integration	Theory Conceptualization and Visualization

Step 1. Determination of potential topics that could be used as the basis for a subjective analysis of complexity topics in mega construction projects

Step 1.1. Cluster and Word Cloud Analysis

Before initiating the coding process, the raw data from the interviews was picturized with the help of word cloud analysis and cluster analysis found in the software. Word clouds are commonly used for representations of word frequency that give greater prominence to words that appear more frequently in a source. Figure 5.3 visualizes the result of word cloud analysis of the entire coding. It is seen that the words "project," "time," "mega," "consequence," "risk," and "contract" are most highlighted in their abstracts.

Figure 5.3 Word cloud analysis for the entire codes

Step 1.2. Queries in NVivo

The query option of NVivo was used to get more detail before coding. Since a text search query was run, a list of all selected data that contain the word or phrase was listed, it helps to see if an idea or topic is prevalent in the interview, explore for any expressions used more widely in the project, and search for concepts that include similar words. Patterns by grouping sources that include similar words were depicted by the cluster analysis module in NVivo. Attribute value similarity, coding similarity, and word similarity are the options to conduct the cluster analysis. Since the data was not coded in NVivo yet, the cluster analysis was conducted by word similarity. Three types of similarity metrics, including Sørensen's Coefficient, Jaccard's Coefficient, and Pearson Correlation Coefficient can be adopted for cluster analysis. By comparing the cluster analysis results based on the three similarity metrics, grouping the interview data using Pearson Correlation Coefficient was most reasonable. Sources that had a higher degree of similarity based on the frequency of words were clustered together, and vice versa. So, the various contexts in which the word or phrase occurs was represented with a tree with branches. It helped to understand the relationships of some factors at first sight. For instance, to understand the relationship between experience and complexity in Project A, a text search query was easy to find. (See Figure 5.4).

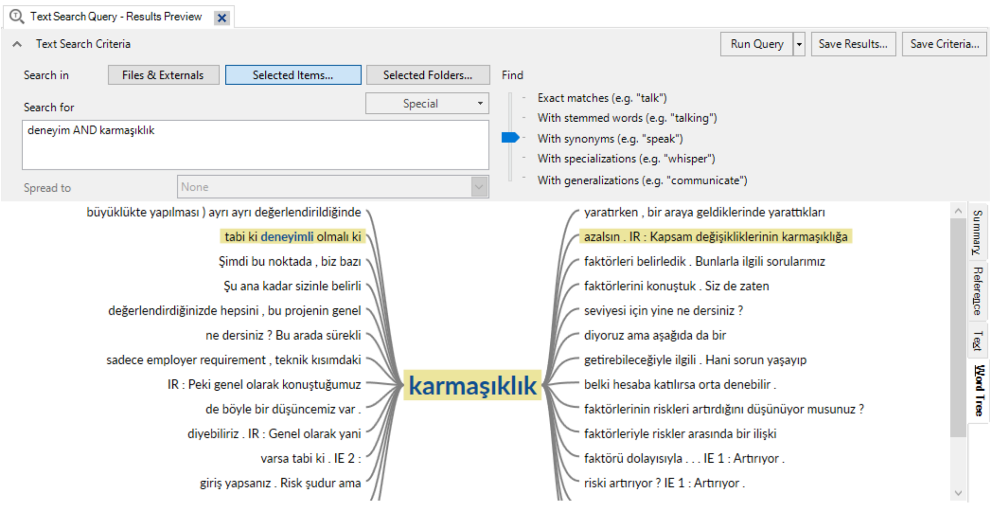

Figure 5.4 An example of text search query

In addition to queries, word cloud analysis helps to get keywords for exploring each interview's potential research topic. The result of eleven interviews' word cloud analysis was pictured in Figures 5.5 and 5.6. The keywords of eleven interviews were adopted to summarize the possible topics of each interview.

(1) Project A

(2) Project B

(3) Project C

(4) Project D

(5) Project E

(6) Project F

Figure 5.5 Word cloud analysis for first six project

(7) Project G

(8) Project H

(9) Project I

(10) Project J

(11) Project K

Figure 5.6 Word cloud analysis for each interview

Step 2. Textual coding as a preparation of open coding

Textual coding began by applying index codes to the data, creating respondent memos, and starting cross-case conceptual memos. The inverse of the line-by-line coding, index codes represented large chunks of text, enabling data reduction and retrieval while the argument is constructing. In other words, it was the relevant text related only to the research concerns. The text related to the specific research concerns was called relevant text and used for further analysis (Auerbach and Silverstein, 2003). Setting the data up this way allowed analytic coding to be more reliable since subsequent rounds of reading could be more focused (Deterding and Waters, 2018). Since a logical starting point for designing the index was the interview structure, including a code for each question on the semistructured interview helped to become familiar with the data through an in-depth reading of the transcript and enable easy test location and retrieval. NVivo's feature named "matrix coding query" was useful for capturing index codes ultimately. Since it showed the coding intersections or co-occurrence of themes with creating a chart of all codes and transcripts, it enabled to show transcripts appear to be missing information.

Step 3. Open/Initial coding

During open coding, several questions were asked and followed to understand the actions in the data which are:

- What is this data a study of? (Glaser, 1978; Glaser and Strauss, 1967)
- What is actually happening in the data?
- What does the data suggest?
- From whose point of view?
- What theoretical category does this specific datum indicate? (Glaser, 1978)

Step 3.1. Incident-by-Incident Coding

In accordance with the questions, line-by-line coding, segment-by-segment, or incident-by-incident coding was the initial step. Since concrete, behavioristic descriptions of participants' actions were not always appropriate to line-by-line coding (Charmaz, 2006), in this research, line-by-line coding was only used when it was necessary.

While open coding, some strategies used (Charmaz, 2000):

- Taking the data apart into their properties
- Identifying the action
- Searching for tacit assumptions
- Explaining implicit actions and meanings
- Clarifying the importance of the points
- Comparing data with data
- Defining gaps in the data

Step 3.2. Constant Comparison

Constant comparison methods were started and used to establish analytic distinctions (Glaser and Strauss, 1967) since data was compared with data to catch differences and similarities. For instance, comparion of interview incidents, in other words, making sequential comparisons helped to gain more awareness of the concepts that were imposed on the data. While performing open coding with a free node function in NVivo to code data, it was seen that same or similar words and phrases were expressed by different participants to state the same idea. These ideas were called repeating ideas, and they sheded light on the research concerns (Deterding and Waters, 2018). While coding, it was realized that there were groups of repeating ideas that had something common.

Step 3.3. Grouping and Organizing Repeating Ideas

Repeating ideas were grouped and organized in a more exacting code. Each phrase, sentence or paragraph in the interview data that signified the child nodes (known as codes) was coded as a reference of the corresponding child nodes. Then, through comparing data to data, the initial focused codes, in other words, parent nodes, were developed. In later steps, with using the logic and strategies of open coding correctly, it was realized that some of the initial codes lead to developing theoretical categories. An example screenshot of the open coding process in NVivo is given in Figure 5.7.

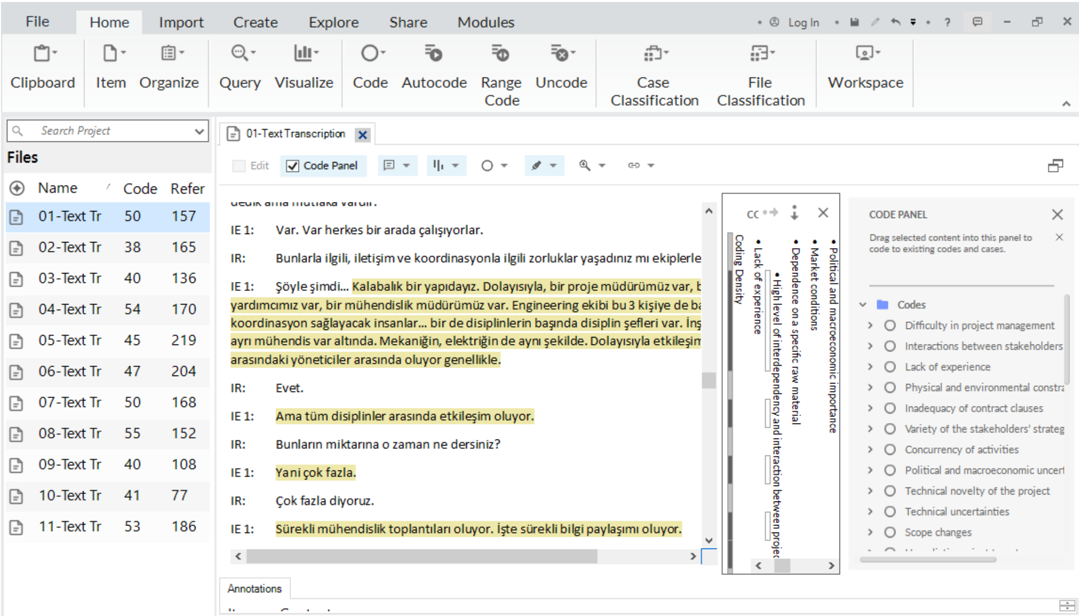

Figure 5.7 A sample of coding analysis on the transcriptions in the dataset created with NVivo.

Step 4. Axial Coding

Axial coding were performed to relate the codes (parent and child nodes), in other words, categories to subcategories (Strauss and Corbin, 1990; 1998).

Step 4.1. Formal Procedure on linking categories with subcategories

Comparing codes with each other was a necessary process to understand how one relates to another. Since axial coding aimed to create bridge between the categories and subcategories and asks how they are related, several questions such as “when, where, why, who, how, and with what consequences” were answered during axial coding (Strauss and Corbin, 1998).

To make links between categories visible, Strauss and Corbin proposed a set of scientific terms and an organizing scheme to answer the questions above. The organizing scheme needed to be cover conditions, actions/interactions, and consequences.

Step 4.2. Flexible Procedure on linking categories with subcategories

Although formal procedures of Strauss and Corbin for axial coding provided a frame to apply, the frame may extend or limit the vision contingent upon the ability to tolerate ambiguity and restrict the codes they construct. In this research, first, Strauss and Corbin's formal procedure on axial coding was performed. Later, as a more flexible and accepted method, links between subcategories and categories were developed with memos as the maturity of the experiences the categories represent was reached.

Step 5. Selective Coding

Step 5.1. Emergence of Core Variable

After categories were developed, saturation reached, and links between categories and subcategories were performed, a core variable emerged. During this stage of the coding, recurring issues and "related categories" (Glaser, 1998) were focused.

Step 5.2. Enriching Core Variable Via Theoretical Codes

Coding continued selectively for the core variable to enrich the core variable. The way categories fit together in relation to each other in the core variable was via theoretical codes (Glaser, 1978; 2005). Theoretical codes were "empty abstractions" and "models" (Glaser, 2005), which were very advantageous in a theory formed with grounded theory. This process, selective coding, introduced as conceptualizing "how the substantive codes may relate to each other as hypotheses to be integrated into a theory" by Glaser (1978). The main aim was to provide the link between the concern of the researcher and the subjective perspective of the participants. These selective codes were integrative since they not only conceptualized how substantive codes were related but also moved the analytic story in a theoretical direction. From a practical perspective, open and selective coding had almost the same process since both compared ideas, incidences, and writing memos. The only difference was that in selective coding, instead of the raw data, the core variables' categories and properties needed to be focused on.

Step 5.3. Role of Substantive Theory on Theory Generalization

Although formal theories could be generated directly from data, the most accurate way to create a theory was from a substantive one. Since the substantive theory was grounded in the research regarding to one particular area, it was applied to create a strategic link on the formulation and mostly generation of grounded theory. Besides, giving hints in developing probable categories gave initial direction in choosing possible modes of integration (Glaser and Strauss, 1967). Indeed, it became almost automatically a stepping stone to the development of a grounded formal theory.

Step 5.4. Theoretical Saturation

To develop the theory, it was necessary delimiting to become theoretically saturated with the constant comparative method's help. Delimiting occurred at two levels which were the categories and the theory. First, the theory solidified in the sense that major modifications became fewer and fewer as the next incidents of a category to its properties were compared. Later modifications were mainly on the order of clarifying the logic, taking out nonrelevant properties, integrating elaborating details of properties into the major outline of interrelated categories, and-most important-reduction. With delimiting and consequent generalization, forced by constant comparison (including literature review), two essential requirements of the theory were achieved. They were related to simplicity of variables and scope in the theory’s applicability to a wide array of cases.

Step 6. Theory Conceptualization and Visualization

At this phase in qualitative analysis, coded data, a range of memos, and a theory were obtained. The arguments in the memos ensured the contents behind the categories that later turned into the theory's central themes. Indeed, collation of the memos based on categories for writing the theory was essential. Therefore, all memos for summarizing and, if needed, further analyzing were brought together before writing the theory. Moreover, to validate the suggested point, pinpoint data behind the theory or gaps in it, and obtain illustrations, coded data were examined again.

Although the theory generation is the substantial aim for grounded theory approach, the findings obtained during QDA are also significant. So that, in the following chapter, findings from the interviews based on coded data are presented project by project. Summary of findings to generate the pattern of perceived project complexity are introduced.

CHAPTER 6

CASE PROJECTS AND FINDINGS FROM THE INTERVIEWS

This chapter introduces information about the case projects and findings from the interviews. First, findings from the interviews are depicted project by project with information about the case projects and expert. Finally, summary of findings obtained from QDA are presented.

6.1 Findings from the Interviews

6.1.1 Project A

Project A is a 1800 MW natural gas combined cycle power plant with an engineering procurement and construction (EPC) contract. The project delivery system is turnkey, and the payment type is lump-sum with milestone payments. Maximum number of employees is between 3000 and 3500. The size of the plant is about 90000 m^2. The situation of the project was under construction at the time of the interview. The contract's scope included the engineering, procurement, and construction works of the power plant, the engineering, procurement, construction, and commissioning activities of all auxiliary systems. General issues related to project A are as follows:

- The project has strategic importance for the country. In addition to meeting the aluminum factory's needs, which will make Bahrain one of the world's largest aluminum producers, it will meet half of the country's energy needs. In this respect, the project is frequently followed by the King.
- Since there were many megaprojects in the region, risks related to the availability of resources due to resource sharing were considerably high.

- Modular systems as a technical newness were used for the first time in the project. Combining parts of the equipment off the field and bringing them to the field as a whole was seen as a significant risk. However, this issue was overcome very quickly with an experienced team.
- The contract stated that large equipments had to be purchased from specific suppliers. This mandatory situation slightly increased the cost.
- Since there was a consortium structure between the main contractor and the company for years, there were no problems in terms of working together. However, it was the first time collaborating with the main contractor’s Dubai team, and due to their dispersed nature, the adjustment process was a bit difficult.
- Due to the very experienced employer and counselor, sometimes the requirements were high, and difficulties were encountered.
- Two claims and more than thirty variation orders were made due to scope changes.
- The design was based on equipment information from the main contractor. In consequence of the high level of interaction necessity, occasional delays were encountered.
- In order to import materials into the country, the employer had to make certain guarantees at customs. At a time when the employer delayed this, it caused a 1.5-month delay.
- There was high level of interaction between both teams in the field and the managers of different disciplines, and it caused coordination and communication related problems.
- Subcontractors brought their workforce from countries such as Pakistan and India. The company also took workers from Turkey to speed things up. This created problems among teams of different nationalities in terms of culture, way of doing business, and speed.
- Since milestones were one month apart and three units of construction were moving simultaneously, there was a very tight schedule.

- In the project, there was high-level mobility of machinery and equipment rather than personnel. For example, to construct an infrastructure in a region of the construction site, large equipment had to be moved to another location because the crane could not pass.
- It was forbidden to work between 12.00-16.00 due to the extreme heat in the summer, which decreased the pace of productivity.
- Instability of macroeconomic dynamics in Turkey affected the company’s economic situation. During the period, critical managerial changes occured in the company.

The participants' perceptions of the complexity are as follows:

- There is a positive correlation between complexity and events out of control that affecting the project.
- Complexity increases both risks and the impact of risks. For instance, according to Int. 1, for Project A, the construction site's congestion was an initially known complexity factor. Due to the company's economic situation, there were some delays, and the duration needs to be constructed was shortened. Productivity declined as more teams were brought into the field to catch the targeted time. After that, the narrowness and congestion of the construction site made a more significant impact than expected.

In the light of information obtained from the interview, 50 codes was assigned to project A. With using the coding query module of NVivo, it was seen that project A included 157 coded references. After the coding process, since the scope of the theory taken form, the higher level-codes assigned to the project were decreased to 33. These factors may have been found to be negative or positive in the project. However, in a general framework, it was coded relationally with complexity. Higher-level sub factors obtained during the coding phase for project A was:

1. A high number of parallel processes and activities
2. High level of interdependency and interaction between project elements including tasks and organizational units

3. Inadequacy of information exchange between stakeholders
4. Mobility of equipment
5. Narrowness and congestion of construction site
6. Tough weather conditions
7. Political and macroeconomic importance
8. Misaligned expectations and requirements
9. Inadequacy of organizational harmony
10. Number of workers from different cultures involved in the project
11. Inadequacy of stakeholder management system
12. Incomplete and inadequate planning
13. Excess political pressure
14. Level of interactions between stakeholders
15. Lack of experience in working with the stakeholders
16. Unbalanced experience level between stakeholders
17. Resource constraint due to shared use
18. Lack of awareness or understanding of technical processes
19. Diversity of cultural structure among stakeholders
20. Uncertainty related to the payments
21. Inflexible contract clauses
22. Level of interactions between various elements within and outside the project system
23. Unbalanced information exchange between project disciplines
24. Lack of experience with the project type
25. Lack of technical experience
26. Mobility of personnel
27. Uncertainties related to the economic condition
28. Competition
29. Dependence on a specific raw material
30. Market conditions
31. Physical size of the project
32. Ill-defined scope and methods adopted
33. Uncertainty in supply chain

The first three sub-factors in descending order that are most coded according to the number of coding references are shown as “A high number of parallel processes and activities,” “High level of interdependency and interaction between project elements including tasks and organizational units," and "Inadequacy of information exchange between stakeholders."

6.1.2 Project B

Project B is a metro project, in which the delivery system is turnkey. Payment type is bid unit price with progress payment. Maximum number of employee is 5000. The total length of the project is 26 km. The project's scope covers 21.7 km double tunnel construction, 16 cut and cover station construction, 5 km maintenance and repair warehouse line, and electro-mechanical systems supply, installation, and commissioning works of the line. The construction of project was completed. General issues related to project B are as follows:

- The project had strategic importance as it was the first metro of the Anatolian Side.
- The project was initially thought to be a risk-free project, except for a few technical issues.
- The project was deeply affected by political events. Although there seemed to be political stability in the country in general, there were continuous elections that negatively affected the stability. For example, since the project was intended to be used as election propaganda, temporary admission was made two months earlier than usual. During that period, as the line was put into service, instead of 24 hours a day, teams worked 3 hours a day, and to catch the deadline, extra personnel was recruited. Since the final acceptance was delayed due to these reasons, there was a penalty.
- The employer changed the project manager as the consultant delayed the approval processes and slowed down construction.
- Although the terms of the contract were explicit, the unit price tariffs were not clear. That caused disputes overpayment at the end of the project. The fundamental reason was the large electro-mechanical items defined as the lump sum in the unit price items. Due to the difficulties, the project became

an example for similar projects that were made later, and the unit price descriptions were made in much more detail.

- The employer attached great importance to the project, and there was mutual goodwill during the construction. Therefore, problems were solved in practice. However, since the contractor did not secure itself in writing, problems were encountered at the end of the work.
- There had been considerable changes in scope. The project plan in the tender document was not carried out. Due to expropriation problems, there were changes in the construction line's route and, therefore, in the scope of the work.
- According to the contract, items included in the project but were not used during construction were not paid. In the opposite case, considering that the required items were forgotten, the payment was still not made. Since scope changes were interpreted as such, Electro-mechanical disciplines defined as a set of properties created significant problems. While for stations with reduced scope, the payment amount decreased, there was no increase in payment at stations with increased scope. This situation became a "claim" subject. Deficiencies in the contract were the root cause of disputes.
- Although the duration target was realistic initially, deviations from the budget were experienced to catch the deadline since it was opened two months early.
- Due to coordination problems between different disciplines, cases of disassembly and reconstruction were encountered. It is thought that this situation would be less if BIM was used.
- In the project, problems regarding to public interaction were experienced from time to time in the areas close to the settlements. Reaction to noise pollution caused by blasting, opposing to excavations due to fear of earthquakes, and trying to prevent the destruction of green areas were some of the problems encountered. In order to overcome these problems, frequent

informative meetings were held through mukhtars. Public relations was one of the significant parameters in the project.

- In the project, for the first time in the world, the sliding formwork system was used for the walkways in the tunnel instead of the classical manpower-based system.

The participant's perceptions of the complexity are as follows:

- Since metro projects generally involve many disciplines, tunnel construction in the city center is difficult, and the amount/size of the work is too much; this type of project is very complicated.
- Complexity increases risks. In connection with increased risks, quality is also affected.

In the light of information obtained from the interview, 38 codes were assigned to project B. With using the coding query module of NVivo, it was seen that project B included 165 coded references. After the coding process, since the scope of the theory takes form, the higher-level codes assigned to the project are decreased to 24. Higher-level sub-factors obtained during the coding phase for project B was:

1. High degree of public interaction
2. Vagueness in contractual terms
3. A high number of parallel processes and activities
4. Coordination problems
5. Unbalanced experience level between stakeholders
6. Narrowness and congestion of construction site
7. Lack of trust among stakeholders
8. Political interventions
9. Inadequacy of stakeholder management system
10. Excess political pressure
11. Country’s political and economic problems
12. Location of the construction site
13. Physical size of the project
14. Lack of awareness or understanding of technical processes
15. Lack of common goal
16. Slow decision-making mechanisms

17. High number of suppliers, contractors, vendors involved in the project
18. Level of interactions between stakeholders
19. Uncertainties related to the economic condition
20. Uncertainties related to the political structure
21. Unstable political influence
22. Dependence on a specific raw material
23. Ambiguity in design processes
24. Conflicting norms and standards

The first three sub-factors in descending order that are most coded according to number of coding references are shown as “High degree of public interaction”, “Vagueness in contractual terms”, and “A high number of parallel processes and activities”.

6.1.3 Project C

Project C is a hospital project with public-private-partnership (PPP) type. Project delivery system is build-operate-transfer (BOT). Maximum number of employee is 2200. The size of the hospital is 466379 m^2. The hospital was planned to be a 1583 bed integrated health campus that involves a 1283 bed main hospital, a 200 bed physical therapy and rehabilitation hospital, and a 100 bed high security forensic psychiatry hospital. The situation of the project was under operation period at the time of the interview. General issues related to project C are as follows:

- Project C was the first PPP hospital project in Turkey. It was the 9th largest Integrated Health Campus in the world. It had six different branch hospitals. The first high-security forensic psychiatric hospital in Turkey was also located in the scope of the project. Because of these features, the project won the "City Awards" design award.
- The project was of great importance for the goal of achieving European Union standards in health services. Besides, it was thought that such projects would develop domestic and international health tourism.

- Since the project model was Public-Private Partnership, the financiers had a considerable role in the project. Although the project's tender was made in 2011, the project started in 2014 because the banks did not find the investment reasonable. There were also conflicts between the government and financiers. The government tried to keep too much control to not comply with the project system. Banks also wanted more control as they financed the project.
- Stakeholders were generally inexperienced as such a project had not been constructed before.
- The contract was prepared in great detail and consisted of 26 annexes. There was also a separate contract for 20 services during the operating period. According to the contract, the contractor would receive approximately 80 million TL per year with 2011 prices, which would be escalated. However, the state caused problems in the escalation calculation due to the fluctuation in foreign exchange.
- Since the designs used during the tender were insufficient, there were some changes in the scope. Furthermore, the design was revised with respect to changes in the "Minimum Design Standards" booklet published by the Ministry of Health.
- At the time of the project, there were some difficulties in finding a qualified workforce as other PPP, investment and housing projects were carried out. There were also minor difficulties in terms of equipment and material supply.
- According to the participant, if six different hospitals in the project were considered as separate projects and separate teams and managers were assigned to each of them, the work schedule would be more manageable. With the gained experience, such a system was used in subsequent projects.
- There was no problem in terms of construction technology. Some unplanned operations, including jet grouting, were carried out because of ground problems.

The participant's perceptions of the complexity are as follows:

- The design was very challenging as a hospital project of that size was one of the most complex structures that could be built. Many issues such as sterilization, the air handling unit's location, ventilation, movement distances, and operating rooms had to be evaluated together. Also, problems could arise as there was no consensus on various issues from the medical industry. The design made according to the data obtained from bio-medical engineers could cause problems in the operational process. The knowledge learned in the project helped to make the design more smoothly in the following projects.
- The project was considered to be more complex due to (1) complex hospital structure, (2) having six branch hospitals and many unknown theoretical concepts related to them, (3) incompletely planned design (the design was completed while the construction continues), (4) difficulty in finding funding, and (5) having additional operational responsibility.
- Complexity increases the risks.
- Better coordination, better design, and establishing a better project management organization are necessary to decrease the project complexity.

In the light of information obtained from the interview, 40 codes was assigned to project C. With using the coding query module of NVivo, it was seen that project C included 136 coded references. After the coding process, since the scope of the theory takes form, the higher-level codes assigned to the project are decreased to 22. Higher-level sub-factors obtained during the coding phase for project C was:

1. Coordination problems
2. A high number of parallel processes and activities
3. Lack of experience with the project type
4. Political and macroeconomic importance
5. Lack of common understanding
6. Misaligned expectations and requirements
7. Uncertainty related to the payments
8. Physical size of the project
9. Lack of common goal

10. Country’s political and economic problems
11. Inadequacy of stakeholder management system
12. High level of unnecessary bureaucracy
13. Vagueness about project role descriptions
14. High level of interdependency and interaction between project elements including tasks and organizational units
15. Mobility of equipment
16. Innovation and originality in design concepts
17. Tough weather conditions
18. Competition
19. Lack of qualified workforce
20. Resource constraint due to shared use
21. Importance of the project for the company
22. Unfamiliarity with norms and standards

The first three sub factors in descending order that are most coded according to number of coding references are shown as “Coordination problems”, “A high number of parallel processes and activities”, and “Lack of experience with the project type”.

6.1.4 Project D

Project D is a hospital project with a contract based on FIDIC red book. The payment type is the unit price. The project is constructed with utilization of a loan which has been agreed upon in between an international bank and the government of Turkey. The maximum number of the employee is 900 and the total indoor area of the hospital is 250000 m^2 and the land area is 73800 m^2. The hospital is planned to be a 1099-bed with fully-equipped hospital. The situation of the project was under construction at the time of the interview. General issues related to project D are as follows:

- The project D as a strategic health infrastructure, will be one of the hospitals to be used as a center in the potential Istanbul earthquake. The project will enhance the city of Istanbul’s preparedness for a potential earthquake. The project will not only assist the development of the health services provided in the European side of Istanbul but also enable non-stop service during and right after the earthquake.

- The project was a first public hospital to be a candidate for Leed Gold (Green Building) Certificate. The trigeneration system, green roof applications, and lighting fixtures was examples of applications.
- The project was being rebuilt with seismic isolation technology. None of the stakeholders had enough experience to do this type of project since at that time nobody in the world knew about seismic isolation technology. Furthermore, this hospital was the first seismic isolator building in turkey handled by the government. The difference from other hospital projects was that in this project the government learnt construction of hospital with seismic isolators. Therefore, government as the employer was learning to both construct and manage.
- There was an almost fifty percent change in the scope. The reason of the revisions in electro mechanics and architectural concepts were that both the standards of hospital projects and the regulations on hospital construction were changed. In addition to the change in hospital standards, as the Germans made the design, it was revised according to Turkish standards, specifications, and Turkish cultural structure (e.g., adding Gasilhane). There had also been changes as it is made according to German materials and equipment.
- Since the project had complex design and technologies not find in Turkey, there were some difficulties during the construction process.
- Since it was the first time that such a seismic isolator was built, the administration was reluctant to change design or procurement processes.
- The new hospital to be built in two stages was constructed without interrupting the operation of the existing hospital. The first phase of the construction had started while continuing the operation of the existing hospital. When the first phase was completed, and put into operation, the existing building was demolished and the second phase started.

- Because of the location of the project in the city, construction machines, trucks could not enter, and concrete could not be poured during the day. In addition, the continuation of the existing hospital's activities added extra congestion. These situations affected the schedule. The change of the 250 thousand square meter building during the construction phase was troublesome.
- More than 100% additional duration had been received according to the planned schedule.
- Force major issues and political instability negatively affected the country's economy. As the dollar rate increased 4-5 times, the country went into uncertainty and instability. Procurement processes were prolonged due to economic uncertainty. Since most of the equipment was used from abroad, suppliers did not sell materials for a while due to unstable economic conditions.
- There was a lack of coordination at the government levels due to political instability.
- The coordination problems between project teams had been experienced due to so many design changes.
- Some of the examples for the problems between the stakeholders was: (1) Involvement of stakeholders at the end of the project rather than at the beginning, (2) paying attention to the work only when there was a delay, (3) and demanding revisions after the work was complete. However, the biggest problem was a lack of communication between the government units and slowness in their decision-making processes. Although it was a project for the public good, the state's bureaucracy was too much. For instance, a simple license problem turned into a dead-end problem.
- In addition to bureaucracy, processes that include change orders were always done with the employer's approval. In the middle of the project, the employer requested to change to the automation system and establish a full hospital

management system. Then, so many revisions were done with the employer, and the contractor delayed the approval.

- The process of making changes in the project was very complicated. Since the contractor was in charge of the design, there was no direct right to make the design changes. It was on the employer’s side. However, at the end of the day, the contractor was responsible when something went wrong. There was no common acceptance or even coordination between stakeholders.
- Communication problems between the project teams caused by the multicultural/multi-regional structure were experienced from time to time.
- The schedule had become congested due to scope changes. When the communication and coordination problems caused by the scope changes were added, the project turned to the mode of constructing and then preparing the necessary documents.

The participant's perceptions of complexity are as follows:

- The complexity factor increases the risks. Being able to manage the factors that create complexity is the major success. For example, the contractor could not manage the slowness and bureaucracy of the inexperienced employer in making decisions. So, one of the reasons for the delay of the project was stakeholder management.
- The reason why the project was challenging and complicated is (1) lack of coordination within the project stakeholders, (2) constant design revisions, (3) due to location of the project, problems in logistics and supply, (4) due to the foreign company responsible for the design, mismatch of design and Turkish construction technology and design standards, and (5) force significant issues.
- Since a complex task can be done by dividing it piece by piece, it is not hard to do. For megaprojects, there is a necessity to overcome many problems simultaneously. Therefore, not being able to execute the project management part correctly creates complexity.

In the light of information obtained from the interview, 54 codes was assigned to project D. With using the coding query module of NVivo, it was seen that project D included 170 coded references. After the coding process, since the scope of the theory takes form, the higher-level codes assigned to the project are decreased to 35. Higher-level sub-factors obtained during the coding phase for project D was:

1. Inadequacy of stakeholder management system
2. Coordination problems
3. Innovation and originality in design concepts
4. Uncertainties related to the economic condition
5. Lack of experience with the project type
6. Location of the construction site
7. Country’s political and economic problems
8. Lack of technical experience
9. Uncertainties related to the political structure
10. Misaligned expectations and requirements
11. Conflicting norms and standards
12. High level of unnecessary bureaucracy
13. Vagueness about project role descriptions
14. Unbalanced information exchange between project disciplines
15. Changes in project goals, methods, tasks, deliverables, structure, teams, and elements
16. Physical size of the project
17. Newness of construction methods
18. Novelty of technological applications
19. Unclear and unrealistic goals
20. Inadequacy of communication channels
21. Slow decision-making mechanisms
22. Uncertainty related to the payments
23. Vagueness in contractual terms
24. High level of interdependency and interaction between project elements including tasks and organizational units
25. Level of interactions between stakeholders
26. Narrowness and congestion of construction site
27. Unstable political influence
28. Political and macroeconomic importance
29. Novelty of product or construction process

30. Ambiguity in design processes
31. Lack of awareness or understanding of technical processes
32. Unfamiliarity with norms and standards
33. Uncertainty in supply chain
34. Inadequacy of organizational harmony
35. Lack of common goal

The first three sub-factors in descending order that are most coded according to number of coding references are shown as “Inadequacy of stakeholder management system”, “Coordination problems”, and “Innovation and originality in design concepts”.

6.1.5 Project E

Project E is a natural gas pipeline project, in which delivery system is turnkey. The payment type is lump-sum. The maximum number of the employee is 2500. The length of the pipeline is 440 km. The aim of the project is intended to convey the natural gas to other countries. The construction of the project was completed. General issues related to project E are as follows:

- Because project E was a world-class project, there were two significant issues with regard to the importance, which were additional time pressure and commitment to other countries.
- The contractor had to accept a very congested schedule to take the project. For the company, being able to manage the contract was one of the biggest problems. For example, due to time pressure and the necessity of a revision in the contract, the works were divided into two, which are essential and non-essential works.
- Project type brought additional challenges. Due to project time, the chosen construction methods caused some troubles when they combined with time pressure.
- The employer had very high standards. For instance, there were 800 safety supervisors in the field. If the rules related to the speed constraint was not

obeyed, the employer had strict rules that ended up being fired. However, the contractor and other stakeholders didn’t have such a strict working style. Thus, the project was high demanding and out of practice for the contractor.

- As the mechanism were strict, rigid, and demanding, the specification was also very clearly defined. Since it wasn’t interpretable, executing and fulfilling the demanding requirements was complex for the contractor. Therefore, as a contractor, able to meet and manage them properly was a necessity. At this point, the communication with the employer needed to be done correctly.
- Qualified workforce was critical in the pipeline projects and in project E, finding over skilled workforce was challenging because of resource availability. Also, there were long-lasting processes required by the employer, such as training and testing the workforce.
- There were too much equipment and personnel movement in the project. In addition, a practical challenge was added to the project due to a set of rules and procedures added by the employer.
- The season was a critical issue in the project. For example, when the appropriate season was missed, that area could only be entered after months. For this reason, it was necessary to make proper equipment and resource planning in project E.
- There was no budgetary problem. According to the participant, the project would have been troublesome if the contract was in Turkish Lira since the biggest of the costs was the rental of equipment with a dollar index.
- Stakeholders did not want to come to the country for a while due to political instability (to do design verification).
- As the project was a state-supported project and committed by an intergovernmental contract, there were no financial difficulties.
- Due to cultural differences, including different eating, sleeping, and hygiene habits, there had been several problems with teams from different cultures (mainly Indian and Turkish) working together.

- There was a management structure made up of stakeholders who were experienced in pipeline projects.
- There were no communication and coordination deficiencies because of the experienced teams, uncongested construction area, and decreased time pressure.
- The main reason of accurate communication and coordination among stakeholders was constructing the correct project management structure.
- The main reason of completed project within the planned period, and budget was that the decision-making mechanism had worked actively and adequately. According to the participant, it was the biggest showstopper of the companies. As the organization grows, the company’s decision mechanism starts to slow down because of the bureaucracy. In the project E, the partnership and decision-making mechanism worked adequately. The companies could see, analyze correctly and take the right actions due to the pipeline background.

The participant's perceptions of the complexity are as follows:

- The pipeline projects have high level of complexity because of the necessity of proper planning and coordination. Because distance and seasonal constraints are always a problem, it is necessary to plan when, where and how much the resource will be used. Furthermore, it is logistically challenging including the transportation of pipes to the construction site. Dealing with nature is another complexity parameter since the teams have to deal with natural events such as snow or flood.
- Whether the stakeholders had experience in pipeline construction or not is a severe factor in the evaluation of the project as complex. The participant stated that if any stakeholder had no pipeline construction experience, the project's complexity was categorized as highly complex.

- Complexity factors increase risks. However, the definition of complexity varies from project to project since the critical factors of each project are different.

In the light of information obtained from the interview, 45 codes was assigned to project E. With using the coding query module of NVivo, it was seen that project E included 219 coded references. After the coding process, since the scope of the theory takes form, the higher-level codes assigned to the project are decreased to 30. Coding comes from project E contributes to higher-level sub-factors given below:

1. Misaligned expectations and requirements
2. Inflexible contract clauses
3. Inadequacy of stakeholder management system
4. Tough weather conditions
5. Coordination of mobility
6. Excess political pressure
7. Level of interactions between various elements within and outside the project system
8. Lack of experience with the project type
9. Number of workers from different cultures involved in the project
10. Slow decision-making mechanisms
11. Vagueness in contractual terms
12. Mobility of equipment
13. Political and macroeconomic importance
14. High level of interdependency and interaction between project elements including tasks and organizational units
15. Uncertainties related to the economic condition
16. Aggressive project goals
17. Unclear and unrealistic goals
18. Diversity of cultural structure among stakeholders
19. Coordination problems
20. Lack of country-related experience
21. Lack of experience in working with the stakeholders
22. Mobility of personnel
23. Narrowness and congestion of construction site
24. Uncertainties related to the political structure

25. Changes in project goals, methods, tasks, deliverables, structure, teams, and elements
26. Lack of qualified workforce
27. Conflicting norms and standards
28. Ill-defined scope and methods adopted
29. Unfamiliarity with norms and standards
30. Uncertainty in supply chain

The first three sub-factors in descending order that are most coded according to number of coding references are shown as “Misaligned expectations and requirements”, “Inflexible contract clauses”, and “Inadequacy of stakeholder management system”.

6.1.6 Project F

Project F is a hospital project, in which delivery system is turnkey. The payment type is the unit price. The maximum number of the employee is 1500. The size of the hospital is 323650 m^2 with 1190 bed capacity. The scope of the hospital includes a general hospital and oncology centre of excellence. The situation of the project was under construction at the time of the interview. General issues related to project F are as follows:

- The project F is one of three initial seismic base isolated hospitals in Istanbul. Since it is a system that will continue to function in an earthquake, it has an importance for the country, especially for Istanbul. Moreover, since seismic building technology was new for the country, there was also an aspect that improved the sector with the gained experience.
- Since the project F was constructed for the first time, the relevant infrastructure laws and regulations were almost nonexistent.
- There was no proper manufacturer in Turkey. Therefore, during the supply of materials from abroad, the contractor faced several problems.

- Since the stakeholders were inexperienced in hospital construction with seismic isolators, it took a long time to understand the triple pendulum seismic isolator system.
- Building a hospital required a high degree of precision. Operating room standards, hot and cold settings of the rooms were critical issues. Therefore, the usual construction sequences of a building couldn't be followed from time to time.
- The new hospital construction was designed to be built over the existing hospital site with an innovative methodology that enabled the continuity of hospital operations throughout the whole construction period.
- Since the construction area was 50000 m^2 and the designed hospital was approximately 36000 m^2, construction in the congested site created complexity. For this reason, the company used the parking lot of the existing hospital for construction site facilities.
- During the tender, the preliminary design was finished however the final coordination including the coordination of construction, architecture, electrical, mechanical, landscape infrastructures were not completed. The designer had a perception that the contractor had to think about how to construct. For example, the designer designed such a way that without thinking about the construction, the contractor had a hard time to pour concrete on certain areas associated with the insulator. In other words, technical problems to be solved in the construction drawing or shopdrawing were left to the contractor.
- There were many difficult or wrong applications in the design that could not be implemented in reality. Due to insufficient design from the designer, the contractor was also involved in the design processes.
- The scope changes had a severe impact. There were almost fifty percent changes in scope. It brought additional complexity.
- Many difficulties were encountered as the contractual clauses were poorly defined. There were situations where stakeholders could not agree on who

had what responsibility in the contract and who gave what punishment to whom. Some disputes were resolved by bargaining due to vagueness in contractual terms. Lack of practice on the harmonized red book of the FIDIC contract created additional uncertainties. When all of them combined with institutions' inexperience in constructing this type of project and lack of communication among stakeholders, the project was become highly complex.

- Contracts, BOQs, and projects were incompatible with each other. Contract documents and annexes were not consistent with each other. Therefore, the contractor could not know which one was correct due to contradictory and missing expressions.
- Due to the fact that the contract was based on the Dollar, Euro and Turkish Lira, it was less affected by the unpredictable dollar increase caused by economic instability.
- Lack of interdisciplinary coordination was one of the fundamental complexity factors.
- Stakeholders could not communicate with each other. There was a massive miscommunication between the employer and the end-user. Between these two, there was an advisor who was stuck. Moreover, when the designer was added to all of them, there was too much lack of coordination, slowness, and vagueness. In project E, this lack of a common goal caused lots of waste of time.
- There was lack of information transfer between project teams. Moreover, since the lessons learned in the project were not recorded, the information was also lost when the people left.
- The fact that the board of management only focused on profit of the project affected the quality of the work.
- It was necessary to establish an accurate structure for stakeholder and project management to not waste time between making the decisions and integrating them into the project.

The participant's perceptions of the complexity are as follows:

- The complex project is more risk-prone, but complexity is not the only reason for the increased risk. Also, for example, building a villa at a very high altitude involves risks, but it is not complicated. Not all difficulties are complex. If complexity is understood as conflict or something multidisciplinary, it can cause risks. The more cells in the checkerboard or chess, the greater the variation. The complexity naturally increases as the variation increases.
- Complex projects exhibit several properties, including emergent behaviors, self-organization, and non-linear property. As a result, top-down control are very restricted.
- According to the participant, complexity will never go down. The risks created by this, as long as the knowledge does not increase, will not change. It is necessary to understand and evaluate the complexity factors first to be prepared for what they will create. However, in Turkey, problems have to be fixed while "flying the plane."

In the light of information obtained from the interview, 47 codes was assigned to project F. With using the coding query module of NVivo, it was seen that project F included 204 coded references. After the coding process, since the scope of the theory takes form, the higher-level codes assigned to the project are decreased to 29. Higher-level sub-factors obtained during coding phase for project F was:

1. Vagueness in contractual terms
2. Unclear and unrealistic goals
3. Novelty of product or construction process
4. Inadequacy of project management system
5. Level of interactions between various elements within and outside the project system
6. Changes in project goals, methods, tasks, deliverables, structure, teams, and elements
7. Inadequate planning
8. Coordination problems

9. Lack of awareness or understanding of technical processes
10. High level of diversity in stakeholders’ project objectives
11. Inadequacy of information exchange between stakeholders
12. Unbalanced information exchange between project disciplines
13. Unbalanced experience level between stakeholders
14. Novelty of technological applications
15. Level of interactions between stakeholders
16. Lack of experience with the project type
17. Lack of technical experience
18. Lack of qualified workforce
19. Political and macroeconomic importance
20. Country’s political and economic problems
21. Effect of inflation
22. Inadequacy of stakeholder management system
23. Misaligned expectations and requirements
24. Uncertainty related to the payments
25. Inflexible contract clauses
26. High number of suppliers, contractors, vendors involved in the project
27. Innovation and originality in design concepts
28. Uncertainties related to the political structure
29. Lack of common understanding

The first three sub-factors in descending order that are most coded according to number of coding references are shown as “Vagueness in contractual terms”, “Unclear and unrealistic goals”, and “Novelty of product or construction process”.

6.1.7 Project G

Project G is an airport project, in which delivery system is PPP. Payment type includes 3 years construction period plus rental fee in 25 years. Maximum number of employee is approximately 2000. The size of the construction area is 124000 m^2 of usable area in addition to the existing building. The contract includes the construction of a new terminal building, new apron barrier building, new power plant – thermal power center, energy distribution building, parking lot, viaduct and new terminal roads and the demolition of the former domestic terminal building. The construction of project was completed. General issues related to project G are as follows:

- It was an important project as the international airport terminal gave the first image related to the country.
- Project G had a unique design that consisted of the combination of wood and concrete. Therefore, design of the project won several design awards.
- Seawater under the ground of constructed area brought technical difficulties.
- When the project was tendered, the scope was to construct a new domestic terminal and demolish the old one after putting it into operation. However, later, the scope had changed to make a new international terminal.
- Domestic (July 15) and international (Syrian and Russian incidents) political crises, terrorist attacks and changes in currency are complexity factors in the project.
- Stakeholders were very experienced in the project. There were difficulties in meeting international standards for financiers. Especially since continuing the construction and operation simultaneously added an extra difficulty, the financiers were actively following the project in the field.
- Due to high-level experience with this type of project, operation and construction proceeded in harmony. However, relations with the designer needed to be managed well because of the conflicts regarding to aesthetics and budget.
- The cost increased 1.5 times due to the change in scope.
- According to the participants, the factuality of the project goals may vary depending on the period. There was no problem in project G because the system was set up correctly. Nevertheless, if the dollar crisis had occurred 6-8 months ago, severe problems would have occurred.
- Although most of the equipment was supplied from abroad, there was no delay in procurement because of the high experience.

- Due to the scope changes, coordination problems occurred between different disciplines, and difficulties were encountered as planning was carried out while the construction was ongoing.
- During the demolition of old domestic terminal, the demolition was stopped as tenants in the building went to court.

The participants' perceptions of the complexity are as follows:

- The project is a complex project due to changes in scope, conflicts with the designer, difficulties during demolition, public interaction, and technical difficulties on the ground.
- The high number of stakeholders and the various demands of stakeholders increase the complexity of the project.

In the light of information obtained from the interview, 50 codes was assigned to project G. With using the coding query module of NVivo, it was seen that project G included 168 coded references. After the coding process, since the scope of the theory takes form, the higherlevel codes assigned to the project are decreased to 30. Higher-level sub-factors obtained during the coding phase for project G was:

1. Lack of experience with the project type
2. Changes in project goals, methods, tasks, deliverables, structure, teams, and elements
3. Inadequate planning
4. Unclear definitions and meanings
5. High degree of public interaction
6. Uncertainties related to the economic condition
7. Lack of common goal
8. High level of interdependency and interaction between project elements including tasks and organizational units
9. A high number of parallel processes and activities
10. Misaligned expectations and requirements
11. Slow decision-making mechanisms
12. Coordination problems
13. Narrowness and congestion of construction site
14. Uncertainties related to the political structure

15. Changes due to laws and regulations
16. Dependence on a specific raw material
17. Novelty of product or construction process
18. Country's political and economic problems
19. Vagueness in contractual terms
20. Lack of interfaces between various project teams
21. Level of interactions between stakeholders
22. Level of interactions between various elements within and outside the project system
23. Uncertainty in the operation period
24. Innovation and originality in design concepts
25. Political and macroeconomic importance
26. Newness of construction methods
27. Ill-defined scope and methods adopted
28. Hidden agendas
29. Unclear and unrealistic goals
30. High level of diversity in stakeholders' project objectives

The first three sub-factors in descending order that are most coded according to number of coding references are shown as "Lack of experience with the project type", "Changes in project goals, methods, tasks, deliverables, structure, teams, and elements", and "Inadequate planning".

6.1.8 Project H

Project H is a pipeline project, in which delivery system is turnkey. The payment type is lump-sum. The aim of the pipeline project is transportation of crude oil to countries. Maximum number of employee is approximately 13000. The pipeline buried along its entire length is 1076 km in Turkey with four main pump stations, two pressure reduction stations, and one main terminal. The diameter of the pipeline is 42 inches throughout most of Turkey. The construction of the project was completed. General issues related to project H are as follows:

- The project H was one of the projects undertaken under the Republic of Turkey for the first time as a contractor. It was the second largest pipeline project constructed in Turkey and the biggest project in the market of that period. In addition to its geopolitical importance, the project showed the world that companies in Turkey could be successful in world-class standards.

- Government as the contractor of the project was a complexity factor. Due to the slowness of the decision-making mechanism, the project could not reach the required pace. There was a heavy and cumbersome system. Furthermore, although the employer and consultant had enough experience with this type of project and management model, the project model was out of the contractor’s experience.
- Besides heavy obligations stated in the contract, the project had a 500 thousand dollars per day penalty and a 300-million-dollar state guarantee in case of delay due to the lump sum turnkey agreement's funding sanctions.
- The demanded vision was zero casualty and environmental damage. The environmental and health safety requirements and standards were too strict and beyond the contractor’s experience. For instance, there was a 20 km/s speed limit around the construction site.
- The project also had political issues. All stakeholders had their own hidden agendas.
- In the contractor side, nobody knew what to do. In addition to no prior experience regarding pipeline, there was also no trained personnel.
- There were situations of passing through steep slopes from the 60-70 inclined. Advanced engineering techniques had been applied to replace the pipes. Furthermore, there were unfamiliar processes in the design.
- There had been considerable changes in scope. Design in detail engineering was remarkably different compared to the basic design.
- The contract currency was dollar, but there were difficulties in the project as the dollar rate decreased at that time.
- The level of communication and interactions between stakeholders was very high. Despite the necessity of multidisciplinary interactions, there was a lack of information exchange.

- Long-time items such as pipe production were supplied from abroad. If pipeline construction was not managed with proper logistics and accurate planning, it would become complex. Since the nature of pipeline construction comprised sequential activities in no man's land, it was always open to surprises.
- There were problems caused by multiculturalism. Communication, understanding of culture, and coordination of them were complicated.
- Since the pipeline passed through the region without civilization, difficulties regarding to the public interaction was encountered such as armed attacks and ransom demands.

The participant's perceptions of the complexity are as follows:

- Even if the contractor has complete information about the system, there is always uncertainty and complexity at some level.
- Collection of factors (such as being a megaproject, having a collecting organization structure, no experience with stakeholders, no experience with the project type, employer's no experience with the country, no experience in being contractor) created complexity in this project.
- Complexity reduces control. When the control decreases, the visible risks increase.
- Regardless of the contractor's experience with megaprojects, there is a complexity that cannot be managed. Because no stakeholder can be the sole owner of the project. But there is also manageable complexity. The manageable part can be dominated by factors such as experience, teamwork, data exchange, using the right data, and proper technology.

In the light of information obtained from the interview, 55 codes was assigned to project H. With using the coding query module of NVivo, it was seen that project H included 152 coded references. After the coding process, since the scope of the theory takes form, the higher-level codes assigned to the project are decreased to 36. Higher-level sub-factors obtained during the coding phase for project H was:

1. Misaligned expectations and requirements
2. Inadequacy of stakeholder management system
3. Lack of experience with the project type
4. Inadequacy of project management system
5. Lack of experience in project role
6. Location of the construction site
7. Uncertainty related to the payments
8. Changes in project goals, methods, tasks, deliverables, structure, teams, and elements
9. Uncertainty in supply chain
10. Lack of common goal
11. A high number of parallel processes and activities
12. Number of workers from different cultures involved in the project
13. Inadequate planning
14. Inflexible contract clauses
15. Uncertainties related to the economic condition
16. Physical size of the project
17. Novelty of product or construction process
18. Lack of awareness or understanding of technical processes
19. Number of different languages used
20. High level of unnecessary bureaucracy
21. Slow decision-making mechanisms
22. Vagueness in contractual terms
23. Excess political pressure
24. High degree of public interaction
25. High level of interdependency and interaction between project elements including tasks and organizational units
26. Level of interactions between stakeholders
27. Level of interactions between various elements within and outside the project system
28. Unbalanced information exchange between project disciplines
29. Lack of country-related experience
30. Lack of technical experience
31. Uncertainties related to the political structure
32. Unstable political influence
33. Importance of the project for the company
34. Political and macroeconomic importance

35. Novelty of technological applications
36. Lack of sense of belonging

The first three sub factors in descending order that are most coded according to number of coding references are shown as “Misaligned expectations and requirements”, “Inadequacy of stakeholder management system”, and “Lack of experience with the project type”.

6.1.9 Project I

Project I is a railway project with EPC contract. The payment type is lump-sum. The length of the railway is 13.5 km. The construction of the project was completed. General issues related to project I are as follows:

- Project I except stopping pollution of the city, it considerably improved Turkey’s railway system. Indeed, the project completed the first high-speed railway line linking the capital city Ankara with Istanbul.
- The originality of the project was combining two continents and having the deepest immersed tube.
- The technology related to the immersed tube was relatively new in the world. There was considerable complexity regarding the construction methods. In the scope of the project I, a deepest immersed tube with a depth of 60 meters and 1.5 m thick diaphragm wall, which was never built in the country until then, was constructed.
- The project's geopolitical location and the construction site in the middle of Istanbul created an additional time pressure. For example, the entrance of trucks or gigantic cranes was very problematic in the center of Istanbul.
- There was a lot of interphase with historical buildings due to the construction in the city center. Archaeological excavations and expropriation problems caused scope changes in the project.

- Since the schedule was very congested and transportation of machines and equipment was complex, transportation-related preliminary preparations needed to be executed accurately.
- Critical resources were procured from abroad, such as TBM. Because of working overseas, communication problems occurred.
- The project was constructed by establishing a high-quality and proper organizational structure with companies having high technical competence.
- As the EPC contract was one of the most challenging contract types to manage, being a contractor with design responsibility added complexity to the project.
- The amount of interaction with stakeholders was low. The main reason was the interaction differences arising from a multicultural structure. For instance, the Japanese were a closed box compared to the Turkish structure.

The participant's perceptions of the complexity are as follows:

- Risks exist even when there is no complexity. Without the complexity factors, these risks have to be mitigated anyway. However, when the complexity factors are added, the risks are thoroughly magnified.

In the light of information obtained from the interview, 40 codes was assigned to project I. With using the coding query module of NVivo, it was seen that project I included 108 coded references. After the coding process, since the scope of the theory takes form, the higher-level codes assigned to the project are decreased to 24. Higher-level sub-factors obtained during the coding phase for project I was:

1. Location of the construction site
2. Diversity of cultural structure among stakeholders
3. Narrowness and congestion of construction site
4. Novelty of technological applications
5. High degree of public interaction
6. Changes in project goals, methods, tasks, deliverables, structure, teams, and elements
7. Inadequacy of communication channels

8. Vagueness in contractual terms
9. Excess political pressure
10. High level of interdependency and interaction between project elements including tasks and organizational units
11. Unbalanced experience level between stakeholders
12. Political and macroeconomic importance
13. Novelty of product or construction process
14. Ambiguity in design processes
15. Lack of awareness or understanding of technical processes
16. Uncertainty in supply chain
17. A high number of parallel processes and activities
18. Misaligned expectations and requirements
19. Inadequate planning
20. Level of interactions between stakeholders
21. Level of interactions between various elements within and outside the project system
22. Physical size of the project
23. Newness of construction methods
24. Inadequacy of organizational harmony

The first three sub factors in descending order that are most coded according to number of coding references are shown as “Location of the construction site”, “Diversity of cultural structure among stakeholders”, and “Narrowness and congestion of construction site”.

6.1.10 Project J

Project J is a highway project with a BOT model. The maximum number of the employee was 8000. The length of the highway was 427 km. The scope of the projects includes 377 km motorway and 44 km connecting roads with 3 km suspension bridge, 30 viaducts, four tunnels, and and 209 bridges. Furthermore, the projects contains toll collection, maintenance and operation centres, and service and park areas. The construction of the project was completed. General issues related to project J are as follows:

- The project J was Turkey's first BOT project and one of the biggest projects in the world. As decreasing the traffic load on the existing route by more than 30%, the new highway reduced the average journey time between the two cities.
- New construction methods were used in the project including an operation that took 19 hours to lift a steel deck between two legs of the bridge.
- The need for interdisciplinary collaboration was very high.
- The project had an exemplary stakeholder and project management structure. Indeed, there were very constructive approaches on the side of the administration. There was sincerity, organizational harmony, and shared understanding among the stakeholders.
- Fluctuations in the dollar currency created severe financial costs in the project.
- There were no communication problems as the companies were not different from each other in terms of company culture.
- To solve the problems regarding public interaction, information and face-to-face meetings were held, and minor changes had been made to the project’s scope to avoid environmental damage.

The participant's perceptions of the complexity are as follows:

- Lack of experience, time constraints, desire for high quality, and participation in the project as an EPC contractor make the project highly complicated. The key factor of decreasing the complexity was both the stakeholders’ and teams’ harmony.
- As a project is a unique endeavor, constructing it at another time will reveal different difficulties. For instance, this time, the road will not fall, but something else will happen. All these technical difficulties can be overcome, but that management part is crucial.

In the light of information obtained from the interview, 41 codes was assigned to project J. With using the coding query module of NVivo, it was seen that project J included 77 coded references. After the coding process, since the scope of the theory takes form, the higher-level codes assigned to the project are decreased to 25. Higher-level sub-factors obtained during the coding phase for project J was:

1. Lack of experience with the project type
2. Uncertainties related to the economic condition
3. A high number of parallel processes and activities
4. Diversity of cultural structure among stakeholders
5. Inadequacy of communication channels
6. Inadequacy of project management system
7. Misaligned expectations and requirements
8. High degree of public interaction
9. Narrowness and congestion of construction site
10. Newness of construction methods
11. Lack of awareness or understanding of technical processes
12. Lack of common goal
13. Inadequacy of stakeholder management system
14. Coordination problems
15. Lack of interfaces between various project teams
16. Uncertainty in the operation period
17. Location of the construction site
18. Changes in project goals, methods, tasks, deliverables, structure, teams, and elements
19. Resource constraint due to shared use
20. Physical size of the project
21. Importance of the project for the company
22. Novelty of product or construction process
23. Novelty of technological applications
24. Inadequacy of organizational harmony
25. Lack of trust among stakeholders

The first three sub-factors in descending order that are most coded according to number of coding references are shown as “Lack of experience with the project type”, “Uncertainties related to the economic condition”, and “A high number of parallel processes and activities”.

6.1.11 Project K

Project K is a power plant project with an EPC contract. The project delivery system is turnkey, and the payment type is lump-sum with milestone payments. The maximum number of the employee is 3000. The construction of the project was completed. It was designed as a dual fuel-fired combined cycle plant with a total nominal capacity of 1500 MW. The simple cycle part of the plant comprises of four gas turbines together with all auxiliaries and relevant equipments of the plant. The plant’s combined cycle part consists of four heat recovery steam generators with all associated systems and equipments. General issues related to project K are as follows:

- The project had strategic importance since it was the first and largest combined-cycle natural gas power plant of Iraq that was built by the private investor.
- There was an inexperienced employer, who generally worked with the Middle Eastern culture, had much money, and wanted to do whatever it wanted with the power of the money. Since there were differences between the two parties' experiences and perspectives, it had been complicated to achieve professional and international management and employer-contractor relationships. Communication with the employer was also complicated, as the employer's intention and the contractor's objectives did not match. For instance, employer didn’t work correctly and on time, and when the employer didn’t even comply with the revised plans, this turned into a complexity factor.
- The consultant was not able to fulfill the expected responsibilities and duties for project K in the Middle Eastern culture. It was not very easy to do it politically either.
- Goals regarding to project duration were very unrealistic and aggressive, considering the employer's experience level.

- Since Iraq was in an environment where there were security problems and terrorism, foreigners could not travel within the city without private armed security. The construction sites were surrounded by protection built with stone walls, transportation of the materials was problematic, and the primary needs for a plant, water supply, were troublesome. In terms of security, the procurement of materials could not be appropriately provided on time. Moreover, providing the necessary workforce and obtaining the necessary work permits were complicated, especially when Iraq and the employer were considered. Therefore, it was one of the most challenging environments for a project to be executed, not just economically and politically.
- There were complex and troubled processes arising from the financial package.
- Many different disciplines had to work in the same area simultaneously, as massive equipment was being assembled in a building and the construction of the building was completed at the same time.
- As power plant projects had to fit in a very narrow area, the project had difficulties due to the complexity of the design. For instance, the necessity for the large equipment, especially gas turbines and generators, to be enclosed in a restricted area and the employer's design-related requests caused additional complexity.

The participant's perceptions of the complexity are as follows:

- The project K became very complex when factors such as being in Iraq, being a megaproject, being an EPC project, designing, being a turnkey lump sum project, having aggressive time targets, and being done to a private investor.
- The more complex work is, the riskier it is. Uncomprehended complexity may be dismissed as noise, but dismissing the pioneer noise will only increase risks rather than disappear the complexity in the project.

In the light of information obtained from the interview, 53 codes was assigned to project K. With using the coding query module of NVivo, it was seen that project K included 186 coded references. After the coding process, since the scope of the theory takes form, the higher-level codes assigned to the project are decreased to 33. Higher-level sub-factors obtained during the coding phase for project K was:

1. Inadequacy of stakeholder management system
2. Country's political and economic problems
3. Unclear and unrealistic goals
4. Lack of experience with the project type
5. Lack of common understanding
6. Physical size of the project
7. Misaligned expectations and requirements
8. Uncertainty related to the payments
9. Uncertainties related to the political structure
10. A high number of parallel processes and activities
11. Inadequacy of project management system
12. Incomplete planning
13. Coordination problems
14. High number of suppliers, contractors, vendors involved in the project
15. Level of interactions between stakeholders
16. Lack of country-related experience
17. Lack of experience in working with the stakeholders
18. Unbalanced experience level between stakeholders
19. Tough weather conditions
20. Political interventions
21. Diversity of cultural structure among stakeholders
22. Number of different languages used
23. Number of workers from different cultures involved in the project
24. Vagueness about project role descriptions
25. Excess political pressure
26. High level of interdependency and interaction between project elements including tasks and organizational units
27. Mobility of equipment
28. Innovation and originality in design concepts
29. Narrowness and congestion of construction site
30. Unstable political influence
31. Dependence on a specific raw material
32. Resource constraint due to shared use
33. Uncertainty in supply chain

The first three sub factors in descending order that are most coded according to number of coding references are shown as “Inadequacy of stakeholder management system”, “Country’s political and economic problems”, and “Unclear and unrealistic goals”.

6.2 Summary of Findings

First of all, it has to be noted that all of the participants indicated the case study projects as “complex”. Upon completing the data analysis, the main factors associated with the concept of complexity were determined, as shown in Table 6.1. 23 remarkable higher-level complexity factors were found. The column of “Number of Coding References” given in the table indicates how many times the coding has been done. For instance, while there are 22 sub-coding for the difficulty in project management (e.g., high level of unnecessary bureaucracy), these are mentioned 156 times in all interview data. The sub-coding is grouped appropriately to form sub-factors. To exemplify, while size of the area to be constructed, amount of resources involved, size of the workforce, volume of financial resources is sub-coding of “physical” and “monetary size” of the project, the complexity factor is defined as “size of the project”. The column of “ # of Coded Project” indicates the related complexity factor is coded how many different projects. Distribution of coded each higher-level complexity factors according to the projects are given in Table 6.2.

Table 6.1 List of higher-level complexity factors

No	Complexity Factor	# of Coding References	# of Coded Project	Sub-factors
1	Difficulty in project management	156	11	Inadequacy of project management system; Inadequacy of communication channels; High level of unnecessary bureaucracy; Vagueness about project role descriptions; Slow decision-making mechanisms; Inadequacy of stakeholder management system; Misaligned expectations and requirements
2	Interactions between stakeholders	142	11	Level of interactions between various elements within and outside the project system; Inadequacy of information exchange between stakeholders; Level of interactions between stakeholders; Excess political pressure; Coordination problems; Lack of interfaces between various project teams; Unbalanced information exchange between project disciplines; High level of interdependency and interaction between project elements including tasks and organizational units; High number of suppliers, contractors, vendors involved in the project
3	Lack of experience	100	11	Lack of experience with the project type; Lack of experience in working with the stakeholders; Teams' lack of experience in working with each other; Lack of country-related experience; Lack of technical experience; Unbalanced experience level between stakeholders; Lack of experience in project role
4	Physical and environmental constraints	69	10	Narrowness and congestion of construction site; Tough weather conditions; Location of the construction site
5	Inadequacy of contract clauses	68	8	Vagueness in contractual terms; Inflexible contract clauses
6	Variety of the stakeholders' strategic goals	56	10	Lack of common goal; Lack of common understanding; Inadequacy of organizational harmony; Lack of sense of belonging; High level of diversity in stakeholders' project objectives; Lack of trust among stakeholders
7	Concurrent activities	44	8	A high number of parallel processes and activities
8	Political and macroeconomic uncertainties in the country	44	9	Uncertainties related to the political structure; Uncertainties related to the economic condition; Unstable political influence

Table 6.1 (Cont'd) List of higher-level complexity factors

No	Complexity Factor	# of Coding References	# of Coded Project	Sub-factors
10	Technical uncertainties	34	10	Ambiguity in design processes; Lack of awareness or understanding of technical processes; Unfamiliarity with norms and standards; Ill-defined scope and methods adopted; Conflicting norms and standards
11	Scope changes	34	7	Changes in project goals, methods, tasks, deliverables, structure, teams, and elements; Changes due to laws and regulations
12	Unrealistic project targets	34	5	Unclear and unrealistic goals; Unclear definitions/meanings; Hidden agendas; Aggressive project goals
13	Country conditions	33	6	Country's political and economic problems; Effect of inflation; Political interventions
14	Inadequacy in project planning	31	6	Incomplete and inadequate planning
15	Size of the project	26	8	Physical size of the project; Monetary size of the project
16	Strategic importance of the project	25	9	Importance of the project for the company; Political and macroeconomic importance
17	Cultural diversity	23	6	Diversity of cultural structure among stakeholders; Number of workers from different cultures involved in the project; Number of different languages used
18	Shortage of resources	23	8	Resource constraint due to shared use; Dependence on a specific raw material; Market conditions; Competition; Lack of qualified workforce
19	Mobility at the construction site	19	4	Mobility of equipment, Mobility of personnel, Coordination of mobility
20	Financial uncertainty	14	6	Uncertainty related to the payments
21	Originality of design	12	5	Innovation and originality in design concepts
22	Uncertainty in logistics	10	6	Uncertainty in supply chain
23	Operational uncertainty	3	3	Uncertainty in the operation period

Table 6.2 Distribution of coded complexity factors according to the projects

Complexity Factor	Project A	Project B	Project C	Project D	Project E	Project F	Project G	Project H	Project I	Project J	Project K
Difficulty in project management											
Interactions between stakeholders											
Lack of experience											
Physical and environmental constraints											
Inadequacy of contract clauses											
Variety of the stakeholders' strategic goals											
Concurrent activities											
Political and macroeconomic uncertainties in the country											
Technical novelty of the project											
Technical uncertainties											
Scope changes											
Unrealistic project targets											
Country conditions											
Inadequacy in project planning											
Size of the project											
Strategic importance of the project											
Cultural diversity											
Shortage of resources											
Mobility at the construction site											
Financial uncertainty											
Originality of design											
Uncertainty in logistics											
Operational uncertainty											

Although individual complexity factors give knowledge about complexity in a project, it is not enough to identify individual complexity factors or clusters of factors to understand the level of project complexity. To understand complexity rather than individual factors, a “pattern of complexity” has to be considered. In the next chapter, findings are compared with similar researches in the literature and interrelated accordingly to explore the pattern of complexity.

CHAPTER 7

DISCUSSION OF RESEARCH FINDINGS

This chapter introduces the discussion of findings from the interviews. First, findings regarding project complexity are compared with similar studies in the literature. Second, interrelations between complexity factors are discussed and visualized with concept maps to show the relationships between project complexity factors. Third, the pattern of complexity is explained. Finally, the complexity definition grounded in data is proposed.

7.1 Complexity Factors

According to Table 6.1, the most frequently mentioned theme was the difficulty of project management. It shows that complexity is highly associated with “managerial complexity”. It is not a suprising that an exceptional level of management and managerial competence are necessary for complex projects. Indeed, projects might have been indicated as “complex”, if project management team had difficulties in managing the project. In paralel with the findings, various researchers (such as Vidal and Marle, 2008; Ahn et al., 2017) stated that difficulties with planning and project management result in complexity, and/or project complexity creates difficulties in project management.

Research findings support the argument that while some dimensions of complexity stated by the participants stem from the known characteristics of the project such as size, novelty, and strategic importance of the project, some of them are due to uncertainty stemming from political, economic, and financial conditions and some are due to difficulties stemming from factors such as concurrency of tasks and interactions between the stakeholders. The findings regarding complexity stemming from structural and dynamic elements coincides with several researcher (such as William, 1999 and Whitty and Maylor, 2009). Elements of complexity factors from literature and findings of the current study are compared in Table 7.1.

Table 7.1 Comparison of findings on the factors that create complexity with the literature

Project Complexity Factor	Attributes
Difficulty in project management	Hierarchical structure (Baccarini, 1996; Vidal and Marle, 2008) Variety of project management methods and tools applied (Vidal and Marle, 2008); Company internal politics, empathy and transparency in relationship (ambiguity, hidden information, transparency) (Cicmil and Marshall, 2005; Geraldi and Adlbrecht, 2007; Cooke-Davies et al., 2007); A standardized project methodology usage (Maylor et al., 2008); Number of structures/groups/teams to be coordinated (Vidal and Marle, 2008); Degree of obtaining information (Bakhshi et al., 2016; Luo et al., 2017); Unknown/poorly defined requirements (Bakhshi et al., 2016); Levels of management are involved in project decision-making (Bakhshi et al., 2016); Administrative policies/procedures (Nguyen et al., 2015); Deficient management of suppliers and procurement (Montequín et al., 2018); Lack of Management support (Montequín et al., 2018)
Interactions between stakeholders	Cooperation and communication JV partner, team, etc. (Geraldi and Adlbrecht, 2007; Vidal and Marle, 2008; Bakhshi et al., 2016) Interdependency and interrelation of stakeholders (Baccarini, 1996; Müller and Turner, 2007; Maylor et al., 2008; Vidal and Marle, 2008) Number of stakeholders and their interactions (Müller and Turner, 2007; Maylor et al., 2008); Intensity of involvement (Maylor et al., 2008); Geographic location of the stakeholders (Vidal and Marle, 2008)
Lack of experience	Commercial newness of the project (new partners, team, processes, etc.) (Geraldi and Adlbrecht, 2007); Knowledge (Baccarini, 1996) Experience with parties involved (Maylor et al., 2008; Bakhshi et al., 2016); Previous experience of an organization, manager, team, or stakeholder with such a project (Maylor et al., 2008; Luo et al., 2017)
Physical and environmental constraints	Physical and environmental constraints such as project location, narrowness of construction site (Shenhar and Dvir, 1996; Jaafari, 2003; Little, 2005; Bosch-Rekveldt et al., 2011; Bakhshi et al., 2016; Luo et al., 2017); Geological conditions (Bakhshi et al., 2016; Luo et al., 2017)
Inadequacy of contract clauses	Form of contract (Geraldi and Adlbrecht, 2007; Müller and Turner, 2007; Nguyen et al., 2015; Bakhshi et al., 2016)
Variety of the stakeholders' strategic goals	Multi-objectives, with conflicting goals (Thompson, 1967; Baccarini, 1996; Williams, 1999; Geraldi and Adlbrecht, 2007; Vidal and Marle, 2008); Variety of goals (Geraldi and Adlbrecht, 2007); Lack of a shared vision for the project (Maylor et al., 2008); Hidden agendas between stakeholders (Maylor et al., 2008); Inconsistency of project goals (Luo et al., 2017); Lack of trust among project organization (Luo et al., 2017)
Concurrent activities	Variety of concurrent tasks (Williams, 1999; Ribbers and Schoo, 2002; Geraldi and Adlbrecht, 2007; Vidal and Marle, 2008) Level of concurrent similarly complex programmes (Ribbers and Schoo, 2002) Diversity of tasks and dependence of relationship among tasks (Vidal and Marle, 2008; Luo et al., 2017)
Political and macroeconomic uncertainties in the country	Political and macroeconomic uncertainties in the country (Jaafari, 2003; Geraldi and Adlbrecht, 2007); Environment of changing policy and regulation (Luo et al., 2017); Environment of changing economy (Luo et al., 2017)

Table 7.1 (Cont'd) Comparison of findings on the factors that create complexity with the literature

Project Complexity Factor	Attributes
Technical novelty of the project	Technical and technological newness of the project (Dewar and Hage, 1978; Tatikonda, 1999; Shenhar and Dvir, 2007; Geraldi and Adlbrecht, 2007; Vidal and Marle, 2008; Bosch-Rekveldt et al., 2011; Nguyen et al., 2015; Dao et al., 2016; Bakhshi et al., 2016) Novelty of construction products (Luo et al., 2017)
Technical uncertainties	Uncertainty in technical methods (Geraldi and Adlbrecht, 2007; Maylor et al., 2008; Bakhshi et al., 2016); Using highly difficult technology (Luo et al., 2017); Lack of knowledge of new technology (Luo et al., 2017)
Scope changes	Scope changes (Maylor et al., 2008); Dynamism (i.e., changing information, specifications, change order, etc.) (Geraldi and Adlbrecht, 2007)
Unrealistic project targets	Project targets (Crawford, 2005; Vidal and Marle, 2008; Dao et al., 2016)
Country conditions	Stability project environment (Geraldi and Adlbrecht, 2007; He et al., 2015; Bakhshi et al., 2016) Influence of politics (Nguyen et al., 2015)
Inadequacy in project planning	Project planning and scheduling (Nguyen et al., 2015; Dao et al., 2016) Clear and well-defined requirements, scope, and work packages (Crawford, 2005; Geraldi and Adlbrecht, 2007; Vidal and Marle, 2008; Maylor et al., 2008) Inaccurate cost and time estimations (Montequín et al., 2018)
Size of the project	Size of the project (Weaver, 1991; Williams, 2002; Geraldi and Adlbrecht, 2007; Müller and Turner, 2007; Thomas and Mengel, 2008; Vidal and Marle, 2008; Nguyen et al., 2015)
Strategic importance of the project	Importance of the project (Maylor et al., 2008) Commercial value (Luo et al., 2017)
Cultural diversity	Number of different cultures (Geraldi and Adlbrecht, 2007; Vidal and Marle, 2008; He et al., 2015) Multi-cultural, multi-language (Eriksson et al., 2002; Geraldi and Adlbrecht, 2007; Maylor et al., 2008; Luo et al., 2017) Cultural differences of project organization (Luo et al., 2017)
Shortage of resources	Resource and skills availability (Baccarini, 1996; Hobday, 1998; Crawford et al., 2005; Geraldi and Adlbrecht, 2007; Thomas and Mengel, 2008; Vidal and Marle, 2008; Bakhshi et al., 2016; Luo et al., 2017) Large number of resources (Maylor et al., 2008) Number of companies sharing resources (Vidal and Marle, 2008; Bakhshi et al., 2016)
Mobility at the construction site	Mobility of equipment (Nguyen et al., 2015)
Financial uncertainty	Financial uncertainty (Bakhshi et al., 2016); Sources of funding (Luo et al., 2017)
Originality of design	Design originality (Geraldi and Adlbrecht, 2007; Nguyen et al., 2015) Unusual type of design process (Bakhshi et al., 2016)
Uncertainty in logistics	Uncertainty in combined transportation (Vidal and Marle, 2008)
Operational uncertainty	Operational uncertainty (Girmscheid and Brockmann, 2008)

A visual representation was generated to show the relative importance of concepts based on data analysis findings. Since the process data are notoriously challenging, theory building process could be enriched with using several strategies such as visual representations, visual mapping, alternate template, temporal bracketing, and simulation (Langley, 1999). In this sense, alternative strategies create more openness toward various forms of connecting between data and theory. Since visual representations enable to present enormous information in relatively small area and are used as useful tools to develop and verify theoretical ideas, in this study, in addition to grounded theory, visualizations for making sense of findings is used for the theory building process. Therefore, Figure 7.1 was constructed to summarise findings from semi-structured interviews. Complexity factors listed in Table 6.1 are represented as "stars" in Figure 7.1. Since project complexity is the phenomenon under investigation, it is at the center and the complexity factors are located around it. Location of the factors are done considering two specific criteria, which are the size of the star and its distance from the center. The size of the star (factor) represents the number of related sub-elements encoded into the relevant factor and its distance from the center represents the number of references (frequency) encoded for each factor. This representation allows not only the visualization of complexity factors regarding the megaproject complexity but also facilitates comparing them with each other.

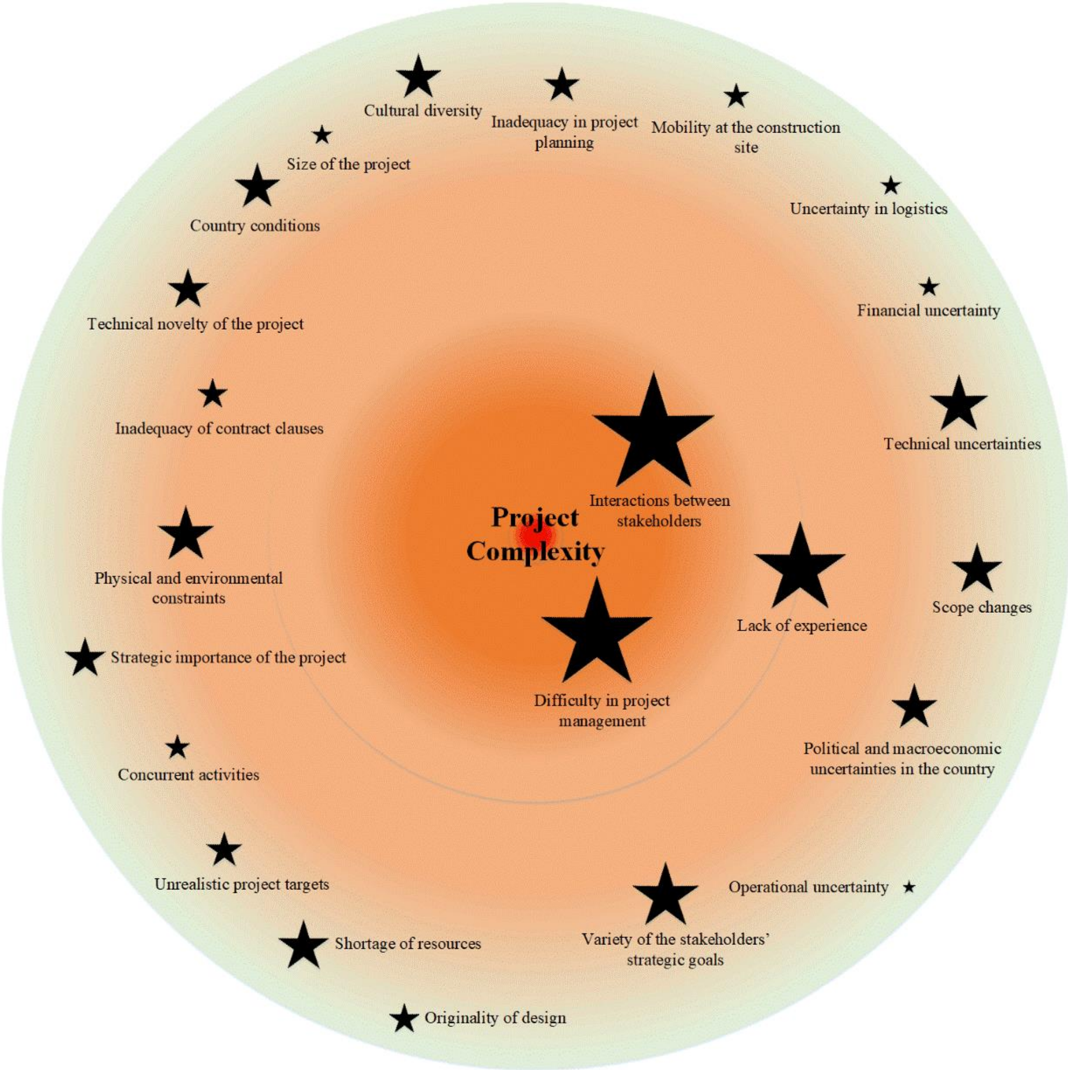

Figure 7.1 Visual representation project complexity and related factors

When the visual representation based on the data analysis is investigated, it is seen that "difficulty in project management," "interactions between stakeholders," and "lack of experience" are the top three factors affecting/related with the project complexity. On the other side, operational factors such as "operational uncertainty," "uncertainty in logistics," and "originality of design" are relatively less influential factors for project complexity. Relative importance of complexity factors among each other closely match with previous research findings such as Vidal et al.'s (2011b), Nguyen et al.'s (2015), and Dao et al.'s (2016). For instance, Dao et al. (2016) generated statistical importance of differences between low-complexity projects and high-complexity projects to idenfity the key contributors of project complexity named as complexity indicators. When Table 6.1 and Figure 7.1 are investigated, it was found that while most significant categories of complexity factors are given as stakeholder management, resource management, governance and fiscal planning, design and technology related factors are relatively low statistical significance. Also, previous researches (e.g., Vidal and Marle, 2008; Bosch-Rekveldt et al., 2011; Qureshi and Kang, 2015) coincide with the dominance of the role of organizational complexity factors and their importance. For instance, in Baccarini's study (1996), the project complexity factors was replaced mainly in the dimension of organizational complexity. Nguyen et al. (2015) developed a method that measures the level of project complexity for transportation projects on a scale of 1-10, based on the complexity factors they determined and their importance weights derived from a fuzzy AHP model. In the research, sociopolitical complexity included four factors as political influence, local experience, number of applicable laws and regulations, and administrative policies or procedures. The organizational complexity was specified as contractual conditions, number of contract or work packages, stakeholders' coordination, and planning of the project. They were the greatest sources of complexity. Operational and technological complexity on the other hand was specified by variety of technologies used and novelty of the technology. It's importance weight on complexity was calculated with fuzzy analytic hierarchy process and it had considerably low significance weight compared to others. In the research of Montequín et al. (2018), complexity was related with project management failure factors. The factors defined by them grouped as factors related to project, organization, the project manager and members of the team, and external environment. One of the remarkable finding was that complexity was referred to the inner properties of the projects and mostly attributed to the managerial conditions. In addition to the reviews, participants also state that managerial and organizational factors are essential for understanding and manageing complex project.

Participants perceived uncertainty as a part of complexity. This implies that participants considered risk and complexity concepts are close and/or related to each other. According to the definition done by Project Management Institute (PMI), risk is “an uncertain event or set of circumstances that, should it occur, will have an effect on achievement of one or more of the project’s objectives” and indeed major source of risk is uncertainty. Despite the fact that many studies (such as Jensen and Aven’s, 2018; Thomé et al.’s, 2016) mentioned about the link between risk and complexity and give insights the relation between risk and complexity, the role of project complexity in risk management has not been studied in detail (Erol et al., 2020). Uncertainty as a part of complexity is managed in projects through risk management (Geraldi et al., 2011) and the risk management process need to include complexity management. According to the findings, as uncertainty is a part of both risk and complexity concepts, they need to be assessed and managed together. In the findings from interview, contract and country-related (e.g., political and economic) uncertainties were mentioned more frequently during the interviews when compared with design-related and technical uncertainties. Since predominantly mega construction projects in a developing counrty, Turkey are carried out, it is more understandable to observe high degree of country-related uncertainties.

In paralel with several studies that offer insights into experience as a significant factor for project complexity (Bakhshi et al., 2016), factor of “lack of experience” is closer to the central concept of complexity than many other critical complexity factors such as size, technical novelty and scope changes in Figure 7.1. Although complex projects comprise simple projects’ subsets, they are not solely reducible to them. In this section, the factors are indicated as stand-alone factors to show the importance on project complexity; however, it is clear that they are interrelated and they influence the level of complexity with their combined impacts.

7.2 Interrelations between Complexity Factors

Consideration of the notes (“memoing”) created during the coding process of data analysis and different views depicted in the literature shows that the concepts could be grouped. In the literature, “Structural complexity,” is presented as the the most mentioned type of complexity and connected with the multiplicity of interrelated parts and interconnected elements (Williams, 1999). One of the other typical behaviour of complex systems is “Emergence”. In this sense, emergent complexity is connected with the concept of “uncertainty” leading to “unpredictability” of project outcomes (Maylor et al., 2008). Based on the critical review, it is seen that complexity related factors obtained from interviews are categorized within the framework of these complexity dimensions. Indeed, findings are grouped as “static complexity” arising from the project’s characteristics and “emergent complexity” related to the factors that emerge over time and are associated with uncertainty. Static and emergent complexity groups obtained from interview data are visualized with concept maps and they are shown in Figure 7.2 and Figure 7.3.

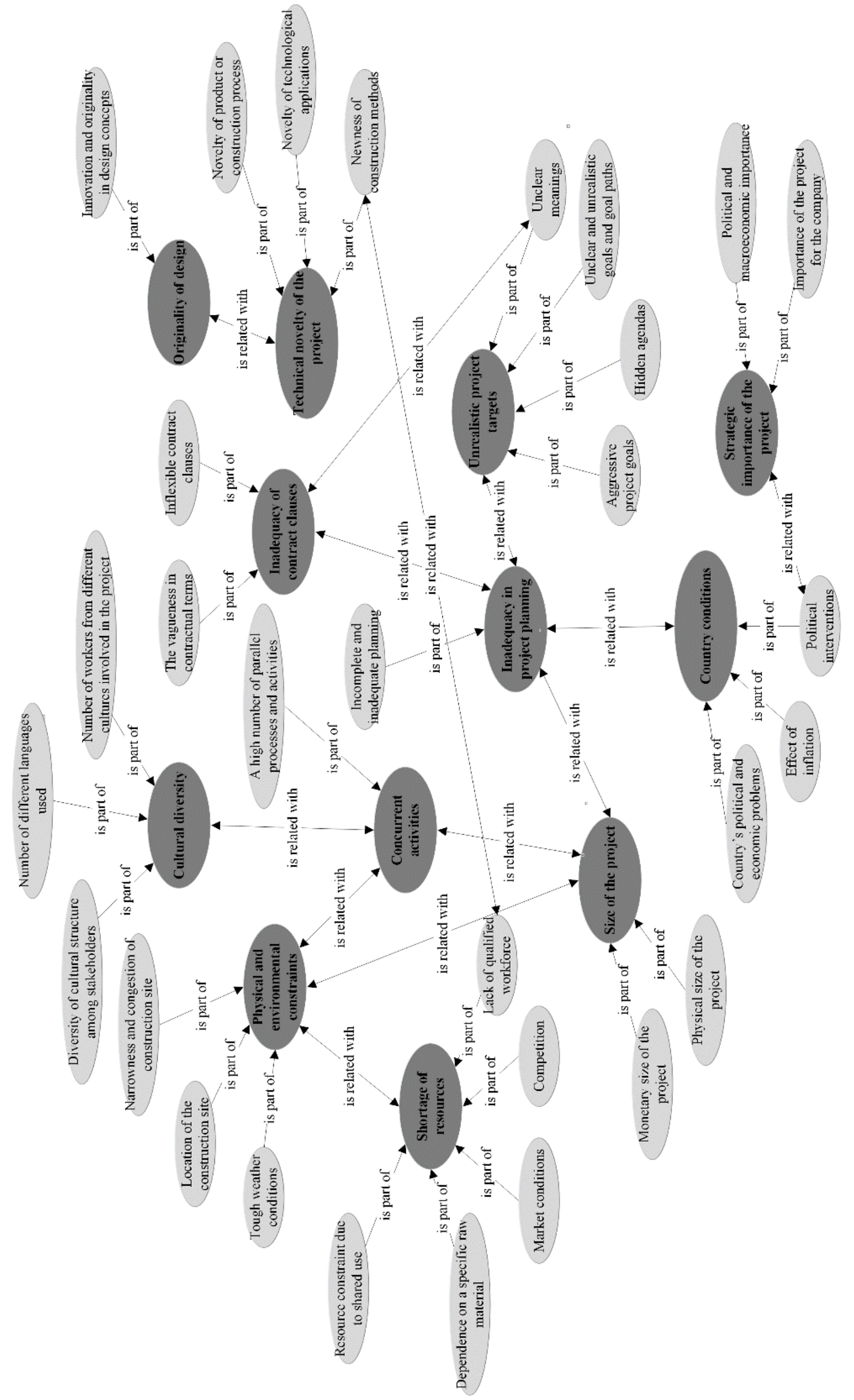

Figure 7.2 Concept map showing structural complexity factors

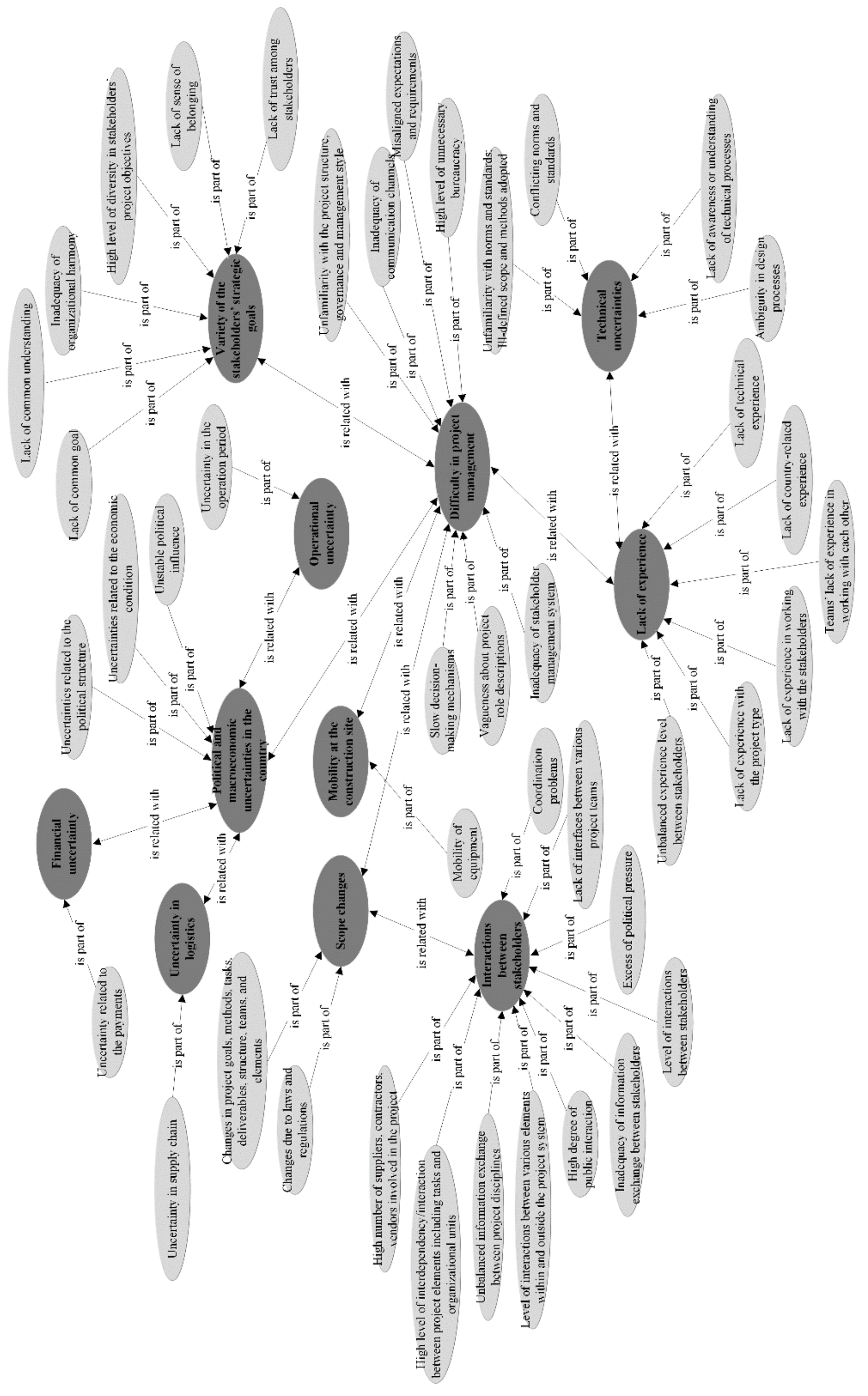

Figure 7.3 Concept map showing emergent complexity factors

The interrelations between concepts within each categories are only represented in Figures 7.2 and 7.3. However, due to the nature of complexity, there also exist several interactions between the categories (static and emergent). During the interview, participants gave several examples about additive effect of the interdepency, non-linearity, and coexistence of factors on project complexity. It indicates that if the complexity factors in in static and emergent complexity categories coexist and interact with each other, they can cause a high degree of complexity in the project. For example, coexistence of high level of unnecessary bureaucracy and slow decision-making mechanism (named as difficulty in project management) and a variety of concurrent tasks (named as concurrent activities) in a mega construction project increase the level of complexity. Similarly, lack of experience in similar projects (named as lack of experience) and existence of site constraints (named as physical constraints) creates additional difficulty in project management and the difficulty, increasing complexity. Some quotations in the projects to indicate the joint effect and interrelations of complexity factors are given in Table 7.2.

Table 7.2 Example quotations about interrelations between the factors

Interviewee	Quotation
Int. 14	In our project, the combination of the originality of design and technical novelty, working with an inexperienced client, the existence of time pressure, and concurrent activities in the construction site resulted in unpredictable results. Uncertainty increased with the unstable macroeconomic conditions.
Int. 6	When unstable political and economic conditions of the country are combined with inadequate planning, this creates a high level of procurement uncertainty. This is something irrecoverable for this type of project.
Int. 9	This project is an association of people, resources, and project structures. These mostly interact with other entities and elements in their environments. In our case, an inexperienced team, difficulties in procurement, and complex contractual arrangements interact with unstable country conditions increasing project complexity.
Int. 1	In almost all projects, project and country-related factors come together, and the level of project complexity increases.
Int. 11	…combination of unrealistic demands of the client, inexperienced project teams, and unstable political and economic situations made the project highly complex…

It is seen that to assess the the level of complexity in a project, rather than analyzing the factors individually, assesing the coexistence and interrations of project complexity factors are necessary.

7.3 Pattern of Complexity

Assesment of project complexity can be done with visualization of overall complexity as a pattern of interacting elements reinforcing or triggering each other. Within the light of interview data, both the individual complexity factors in mega construction projects and their combination to lead reinforcing or triggering effect on project complexity are demonstrated by the representation in Figure 7.4. It should be noted that since the relationships shown in Figure 7.4 are supplied by 18 interviewees and represent only 11 projects, they may not cover all possible interactions between project complexity factors. Although, the input of the representation includes a narrow set, even in its current form, the network structure shows that identification of only individual complexity factors or clusters of factors are not sufficient to understand the level of project complexity. The visualization is obtained in the result of data analysis. In the process data, it is seen that participants highlighted the significant of both the complexity of the factors triggering others or increasing their influences and the complexity created by the coexistence of several factors in the project with their lived experiences. As the exemplified relationships are linked in the axial coding process, arguments related to the combination of factors and their interrelations have been determined using memos and deepened in the selective coding process. In Figure 7.4, as the straight arrow are used to indicate the factors that coexist in the project simultaneously and interact with each other, the triggering effect on each other is indicated with the dotted arrow.

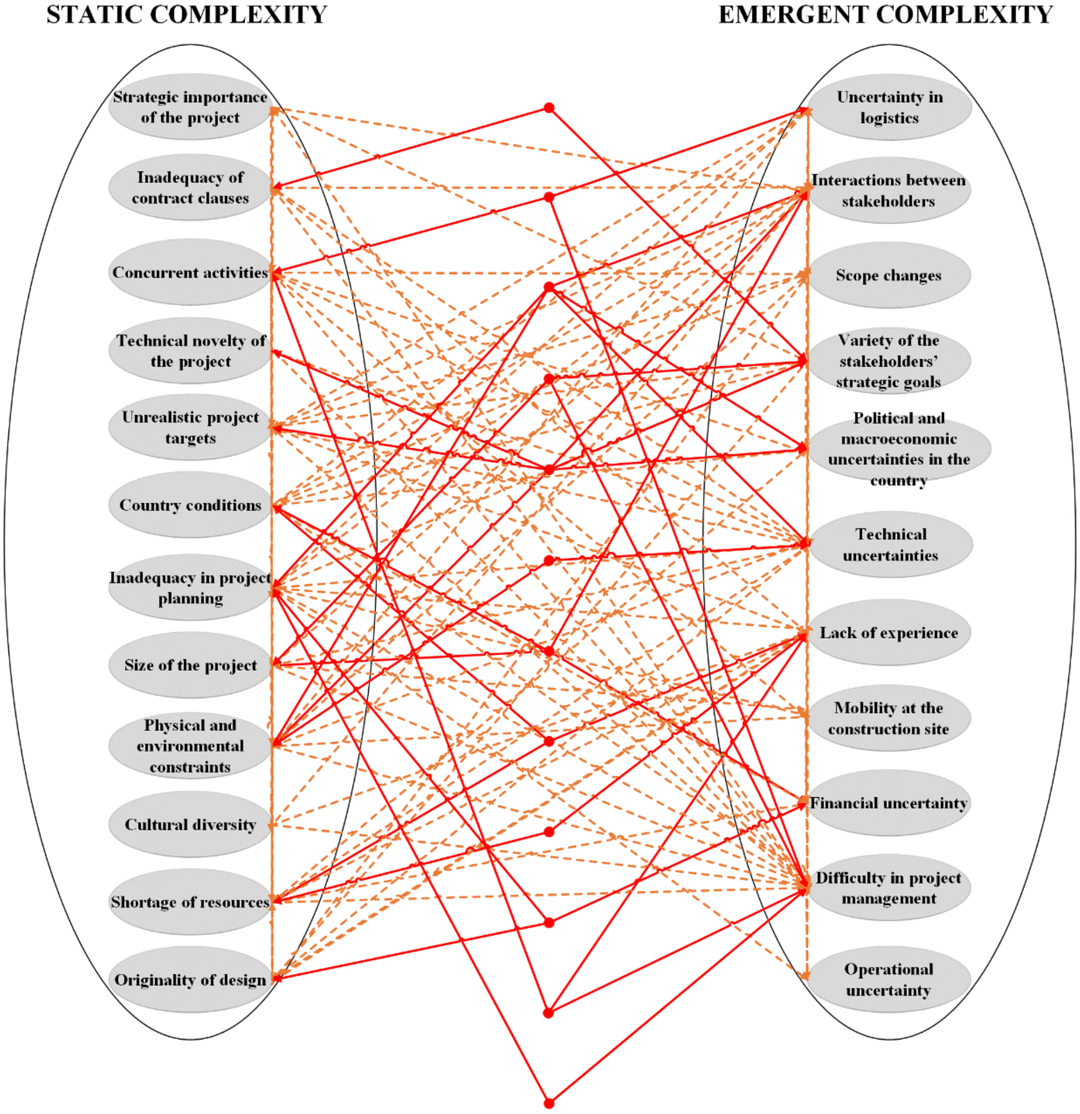

Figure 7.4 Representation of the pattern of complexity

Overall complexity can be visualized as a pattern of interacting elements reinforcing or triggering each other. Although Figure 7.4 is only able to show the static relations between the factors, in reality, it should be noticed that during the project life cycle, emergent factors (such as scope) may change as well as the interrelations between the complexity factors. For instance, the dynamic relations between several factors are also mentioned by some participants and a quotation from the interviews on project D are given below to exemplify the dynamic change. In this quotation, it is observed that a technical complexity first leads to logistical complexity, and then financial complexity:

> *"... As the start of the project, most important problem was technical complexity due to the seismic isolators being used that also lead to delays due to long waiting times for testing and also logistical problems. Then, when the logistical problems were solved, we had a financial problem because of delay of progress payments due to differing requirements of high number of financial institutions involved..."*

The dynamic change of complexity regarding project D is given in Figure 7.5 as an illustration.

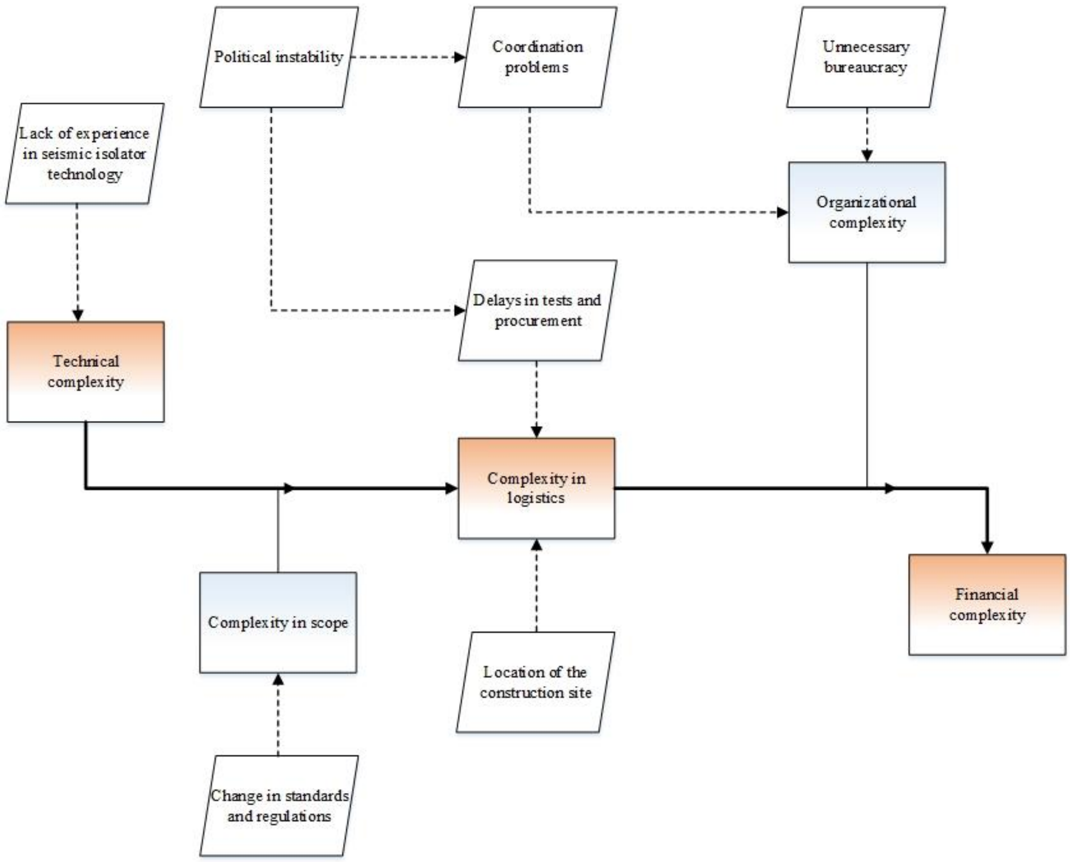

Figure 7.5 An illustration of the dynamic change in complexity

7.4 Definition of Complexity in Mega Construction Projects

Findings show that mega construction projects are open to various complexity factors, and these complexity factors interact with each other in a constantly changing dynamic environment. The complexity of megaprojects are not only depend on static and emergent complexity factors but also interrelations between and coexistence of these factors. Therefore, complexity is not classified as a binary variable. It tends to change over time with respect to changes in emergent factors, interrelations, and correlations. In this sense, with considering a list or hierarchy of individual complexity factors, the complexity cannot be captured and assessed. A pattern that tend to change over time need to conceptualize and assess project complexity. So that, understanding the pattern of complexity rather than listing a group of individual factors are more significant for assessing complexity in a project. In this context, a definition of project complexity has been developed. The definition based on Figure 7.4 is as follows:

> *In mega construction projects, complexity is a project property that stems from project features such as size, stakeholders and strategic importance, and uncertain variables/conditions such as scope, relations and country factors that form a pattern which evolves over time.*

This definition reinforces the argument that degree of complexity that project characteristics and uncertainty factors create when they come together in different combinations and affect each other is not the same as the totality of individual impacts. Furthermore, the definition indicates an emergent pattern which causes to complexity in a project over time. Therefore, assessing and managing complexity in a project needs a full understanding of dynamic complexity patterns.

Although managing complex project is difficult, research findings also indicate that project management team succeed by understanding their project’s complexity patterns. Thus, the developed definition has also some implications for managing complexity. Although deliberate strategies (exploitation) can be used for management of some complexity factors such as high number of stakeholders and operational complexity, emergent strategies (exploration) are needed for uncertainty and ambiguity by the reason of interrelated factors. While some deliberate strategies for especially the structural (static) factors can be enough at the start of a megaproject, emergent factors have to an agile project management approach and a resilient project system that has qualities such as adaptive capacity, absorptive capacity, and restorative capacity (Francis and Bekera, 2014).

A summary of findings regarding the pattern of complexity and perceived definition of complexity in mega construction projects are presented in the next chapter. Contribution of the findings to theory and practice are provided. Limitations regarding the research and recommendations for future studies are evaluated.

CHAPTER 8

SUMMARY OF FINDINGS AND CONCLUSIONS

This chapter introduces the summary of findings and conclusions from the research. First, a summary of findings is presented. Second, contributions to theory and practice are addressed. Third, limitations regarding the research are explained. Finally, this chapter concludes with some recommendations for future work.

8.1 Summary of Findings

This thesis presents an exploratory research to derive a inclusive definition of perceived complexity, in other words, to propose “pattern of complexity”. Data was gathered by way of interviews with 18 Turkish contractors from 11 mega construction projects. Data analysis was acquired through QDA and as the research methodology, grounded theory approach was followed. The process data was enriched with visual representations. Since the process data uncovered what characteristics comprise and factors contribute to the project complexity of mega construction projects, integration of analysis results to visual representatitons uncovered how can pattern of complexity be proposed and effectively represented.

As a result of this research, 23 remarkable higher-level complexity factors with their sub-factors were found. It is seen that some complexity factors stated by the participants stem from the known characteristics of the project such as size, novelty, strategic importance of the project, whereas some of them are due to uncertainty stemming from political, economic and financial conditions. While factors originated from the known project characteristics are given as static complexity factors, factors due to uncertainty are given as emergent complexity factors. Similarly, while complexity factors about project characteristics strongly match with previous research findings such as Williams (1999), Vidal and Marle (2008), uncertainty related factors are also mentioned in previous studies (such as Williams (1999), Qureshi and Kang, 2015; Geraldi et al., 2011).

The definitions of complexity stated in literature of project management and complexity science are generally consistent with the findings. Altough the critical review mainly underline the importance of scale, variety, and interdependencies between elements of the project system as significant project complexity dimensions, the research findings points out the emergent behavior arising out of non-linear (multiple, interdependent, simultaneous) interactions among relatively simple components of a system and coexistence of them. In all of the interviews, in addition to static and emergent complexity factors, their interrelations and reinforcing effects were highlighted. The coexistence and interrelations between these factors were identified as the main source of complexity in the case projects. It indicates that even though the structural aspects such as scale and variety can serve as required pre-conditions, they may not necessarily impart complex behavior by themselves. It is the nature of the coexistence of and interdependencies between these factors that make the difference between complicated and complex behavior.

Furthermore, when the relative importance of the complexity factors among each other was assessed considering the number of times they are mentioned during the interviews, difficulty in project management, interactions between stakeholders, and lack of experience were found as the top three factors affecting the project complexity. Complexity mainly addressed to by participants, with connotations to the challenges associated with management of projects, the challenges related to interactions between stakeholders, and lack of experience in particular. Especially, when the management issues were discussed, the participants mainly define their projects as simple or complex. This shows that due to the high extraordinary management demand of complexity projects, complexity creates a significant difference on project management.

Findings also indicate that factor of “lack of experience” are one of the critical factors for project complexity in developing countries. To understand complex projects, a high level of expertise and knowledge are necessary since eventually the suitable actions are required to come through the challenges. Therefore, the nature of complex projects especially in developing countries is not always related to their scale, but to the issue of specialised expertise and experience. Vulnerability of a project uncertainties and difficulties in project management is affected by lack of experience and unbalanced experience of stakeholders.

8.2 Contributions to Theory and Practice

Findings reinforce the idea that project complexity should be better conceptualized and assessed by a pattern rather than a list or hierarchy of individual complexity factors. Furthermore, it was founded that level of complexity requires a dynamic modelling approach for complexity assessment and when the emergent factors and interrelations change over time, level of complexity changes.

Since this study identified a complexity pattern based on interviews with experts involved in 11 mega construction projects and compare findings with previous researches, it has a potential to contribute the body of project management knowledge. Also, findings of this study provide some insights about process of managing risk in projects. Uncertainty as a source and consequence of complexity implies that complexity should be considered during risk assessment and management. In this sense, the complexity pattern can be used for contingency plans in project risk management. Since the purpose of the contingecy plan is to lessen the damage of the risk when it occurs, the complexity pattern can be also considered for accurate planning. Furthermore, identified complexity pattern can be used for risk management during bidding and contract negotiations stages. It might impact the bidder’s ability to quantify the anticipated time and cost of the potential complexity, risks and opportunities encountered throughout the project lifecycle.

8.3 Limitations of the Research

The major limitation of the research is that conceptualized project complexity concept is based on a limited number of case study. In the research, 11 sample megaprojects in the construction industry were used. Therefore, findings can not be generalized. In this sense, further studies are required. Furthermore, the findings only reflect the experience of Turkish construction practitioners, and mainly mega construction projects carried out in Turkey. Since data obtained from the interviews predominantly includes mega construction projects in Turkey, findings could be different if the same study was carried out in a developed country instead of developing country. Also, carrying out the same study with experts with different nationalities could indicate different complexity factors or change the overall complexity factors' relative importance. Additional studies can be performed and compared to test the findings' relevancy for countries and other project-based industries. Since QDA was conducted in this thesis, only qualitatively discerned dimensions of complexity was involved.

8.4 Recommendations for Future Studies

Forthcoming studies can involve further research on the concept maps and conceptual patterns defined in this qualitative study to develop quantitative models. With the help of this future models, level of complexity in mega construction projects can be predicted. Moreover, since the study only qualitatively discerned dimensions of complexity, a proof-of-concept stage with a quantitative measurement can also be further utilized.

This study has some implications for management of complexity. In the interviews, specific operational responses with respect to dealing with the project complexity related challenges was also given by participants. The relationship between project complexity and project success moderated by project management competencies and organizational responses can be examined. Indeed, future empirical studies can evaluate the impact of implemented strategies responses (such as establishing resilient project systems etc.) on the success of mega construction projects, and managerial suggestions can be built. Considering the complexity pattern identified in this study, systems dynamics can be used to model project complexity and mega construction projects can be modelled as complex adaptive systems.

REFERENCES

Ahn, S., Shokri, S., Lee, S., Haas, C.T., & Haas, R.C.G. (2017). Exploratory study on the effectiveness of interface-management practices in dealing with project complexity in large-scale engineering and construction projects. *Journal of Management in Engineering*, 33(2), 04016039. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000488.

Alderman, N., Ivory, C., McLoughlin, I., & Vaughan, R. (2005). Sense-making as a process within complex service-led projects. *International Journal of Project Management*, 23(5), 380–385. https://doi.org/10.1016/j.ijproman.2005.01.004.

Atkinson, R., Crawford, L., & Ward, S. (2006). Fundamental uncertainties in projects and the scope of project management. *International Journal of Project Management*, 24(8), 687–698.

Baccarini, D. (1996). The concept of project complexity—A review. *International Journal of Project Management*, 14(4), 201–204. https://doi.org/10.1016/0263-7863(95)00093-3.

Bakhshi, J., Ireland, V., & Gorod, A. (2016). Clarifying the project complexity construct: Past, present and future. *International Journal of Project Management*, 34(7), 1199–1213. https://doi.org/10.1016/j.ijproman.2016.06.002.

Bjorvatn, T., & Wald, A. (2018). Project complexity and team-level absorptive capacity as drivers of project management performance. *International Journal of Project Management*, 36(6), 876–888.

https://doi.org/10.1016/j.ijproman.2018.05.003.

Boateng, P. (2014). *A dynamic systems approach to risk assessment in megaprojects*. [Doctoral dissertation, Heriot-Watt University, UK].

Bosch-Rekveldt, M., Jongkind, Y., Mooi, H., Bakker, H., & Verbraeck, A. (2011). Grasping project complexity in large engineering projects: The TOE (Technical, Organizational and Environmental) framework. *International Journal of Project Management*, 29(6), 728–739. https://doi.org/10.1016/j.ijproman.2010.07.008.

Botchkarev, A., & Finnigan, P. (2015). Complexity in the Context of Information Systems Project Management. *Organisational Project Management*, University of Technology, Sydney (UTS), 2(1), 15. https://doi.org/10.5130/opm.v2i1.4272.

Bringer, J.D, Johnston, L.H., & Brackenridge, C.H. (2004). The complexities of writing about the use of QSR*NVIVO within a grounded theory study. *Qualitative Research*, 4(2), 247–265. https://doi.org/10.1177/1468794104044434.

Brockmann, D. I. C., & Girmscheid, I. G. (2007). Complexity of Megaprojects. *CIB World Building Congress 2007*, Cape Town, South Africa.

Bryant, A. (2002). Re-Grounding Grounded Theory. *Journal of Information Technology Theory and Application (JITTA)*, 4(1), Article 7. Available at: https://aisel.aisnet.org/jitta/vol4/iss1/7.

Bryant, A., & Charmaz, K. (2007). *Introduction. Grounded Theory Research: Methods and Practices*. In A. Bryant & K. Charmaz (Eds.), The SAGE handbook of grounded theory. SAGE Publications, Thousand Oaks, CA.

Capka, J. R. (2004). Megaprojects—they are a different breed, *Public Roads*, 68(1), 2–9.

Carvalho, M. M. de, Patah, L. A., & de Souza Bido, D. (2015). Project management and its effects on project success: Cross-country and cross-industry comparisons. International Journal of Project Management, 33(7), 1509–1522. https://doi.org/10.1016/j.ijproman.2015.04.004

Casti, J L. (1994). *Complexification: Explaining a paradoxical world through the science of surprise*. Abacus Ltd, London.

Chapman, R. J. (2016). A framework for examining the dimensions and characteristics of complexity inherent within rail megaprojects. *International Journal of Project Management*, 34(6), 937-956. https://doi.org/10.1016/j.ijproman.2016.05.001.

Charmaz, K. (2000). *Grounded theory: Objectivist and constructivist methods.* In handbook of qualitative research, 509–535, 2nd. ed., SAGE Publications, Thousand Oaks.

Charmaz, K. (2006). Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis. SAGE Publications, Thousand Oaks.

Cicmil, S., & Marshall, D. (2005). Insights into collaboration at the project level: complexity, social interaction and procurement mechanisms. *Building Research & Information*, 33(6), 523–535. https://doi.org/10.1080/09613210500288886.

Cicmil, S., Cooke-Davies, T., Crawford, L., & Richardson, K. (2009). Exploring the Complexity of Projects: Implications of Complexity Theory for Project

Management Practice. (1 ed.) Project Management Institute.

Cicmil, S., Williams, T., Thomas, J., & Hodgson, D. (2006). Rethinking Project Management: Researching the actuality of projects. *International Journal of Project Management,* 24(8), 675–686. https://doi.org/10.1016/j.ijproman.2006.08.006.

Clegg, S., Pitsis, T., Rura-Polley, T., & Marosszeky, M. (2002). Governmentality matters: designing an alliance culture of inter-organisational collaboration for managing projects. *Organization Studies,* 23(3), 317–337. https://doi.org/10.1177/0170840602233001.

Coffey, A., & Atkinson, P. (1996). Making sense of qualitative data: Complementary research strategies. SAGE Publications, Thousand Oaks.

Cooke-Davies, T., Cicmil, S., Crawford, L., & Richardson, K. (2007). We're not in Kansas anymore, Toto: Mapping the strange landscape of complexity theory, and its relationship to project management. *Project Management Journal*, 38(2), 50–61. https://doi.org/10.1177/875697280703800206.

Corbin, J., & Strauss, A. L. (2014). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory.* SAGE Publications.

Corbin, J., & Strauss, A. (2015). *Basics of Qualitative Research.* SAGE Publications, Thousand Oaks.

Crawford, L., Hobbs, B., & Turner, J. R. (2005). Project categorization systems, *Project Management Institute*, Newtown Square, PA.

Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five traditions*. Sage Publications, Inc.

Dao, B., Kermanshachi, S., Shane, J., Anderson, S. & Hare, E. (2017). Exploring and assessing project complexity. *Journal of Construction Engineering and Management*, 143(5), 04016126. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001275.

Dao, B., Kermanshachi, S., Shane, J., Anderson, S., & Hare, E. (2016). Identifying and measuring project complexity. *Procedia Engineering*, 145, 476–482. https://doi.org/10.1016/j.proeng.2016.04.024.

Davies, A., & Mackenzie, I. (2014). Project complexity and systems integration: Constructing the London 2012 Olympics and Paralympics Games. *International Journal of Project Management*, 32(5), 773-790. https://doi.org/10.1016/j.ijproman.2013.10.004.

Davies, E.M., (1973). An experimental investigation of resource allocation in multi-activity projects. *Operations Research Quarterly*, 24 (4), 587–591. https://doi.org/10.1057/jors.1973.107.

Davis, E.W., (1975). Project network summary measures and constrained resource scheduling. *AIIE Transactions*, 7 (2), 132–142. https://doi.org/10.1080/05695557508974995.

Deterding, N. M., & Waters, M. C. (2018). Flexible Coding of In-depth Interviews. *Sociological Methods and Research*, 004912411879937. https://doi.org/10.1177/0049124118799377.

Dewar, R., & Hage, J. (1978). Size, technology, complexity, and structural differentiation: towards a theoretical synthesis. *Administrative Science Quarterly*, 23(1), 111–136. https://doi.org/10.2307/2392436.

Dunne, C. (2011). The place of the literature review in grounded theory research. *International Journal of Social Research Methodology*, 14(2), 111–124. https://doi.org/10.1080/13645579.2010.494930.

Dunović, I. B., Radujković, M., & Škreb, K. A. (2014). Towards a New Model of Complexity – The Case of Large Infrastructure Projects. *Procedia - Social and Behavioral Sciences*, 119, 730–738. https://doi.org/10.1016/j.sbspro.2014.03.082

Edmonds, B. (1999). *Syntactic measures of complexity*. [Doctoral dissertation, University of Manchester, UK].

Eriksson, M., Lilliesköld, J., Jonsson, N., & Novosel, D. (2002). How to manage complex, multinational r&d projects successfully. *Engineering Management Journal*, 14(2), 53–60. https://doi.org/10.1080/10429247.2002.11415163.

Erol, H., Dikmen, I., Atasoy, G., & Birgonul, M.T. (2018). Contemporary Issues in Mega Construction Projects. *5th International Project and Construction Management Conference (IPCMC 2018)*, Cyprus.

Erol, H., Dikmen, I., Atasoy, G., & Birgonul, M.T. (2020). Exploring the relationship between complexity and risk in megaconstruction projects. *Journal of Construction Engineering and Management*, 146(12), 04020138. https://doi.org/10.1061/(asce)co.1943-7862.0001946.

Fendt, J., & Sachs, W. (2007). Grounded Theory Method in Management Research. *Organizational Research Methods*, 11(3), 430–455. https://doi.org/10.1177/1094428106297812.

Fiori, C., & Kovaka, M. (2005). Defining megaprojects: Learning from construction at the edge of experience. *Construction Research Congress 2005*, Reston, VA. https://doi.org/10.1061/40754(183)70.

Flyvbjerg, B. (2009). Survival of the unfittest: why the worst infrastructure gets built - and what we can do about it. *Oxford Review of Economic Policy*, 25(3), 344-367. https://doi.org/10.1093/oxrep/grp024.

Flyvbjerg, B. (2014). What you should know about megaprojects and why: An overview. *Project Management Journal*, 45(2), 6-19. https://doi.org/10.1002/pmj.21409.

Flyvbjerg, B. (2017). *Introduction: The iron law of megaproject management.* In Oxford Handbook of Megaproject Management, 1–18, Oxford University Press.

Flyvbjerg, B., Skamris, M. K., & Buhl, S. L. (2003). How common and how large are cost overruns in transport infrastructure projects?. *Transport Reviews*, 23(1), 71-88.

Francis, R., & Bekera, B. (2014). A metric and frameworks for resilience analysis of engineered and infrastructure systems. *Reliability Engineering & System Safety*, 121, 90–103. https://doi.org/10.1016/j.ress.2013.07.004.

Gell-Mann, M. (1994), *The quark and the jaguar: Adventures in the simple and the complex*, W. H. Freeman, San Francisco.

Geraldi, J. G. (2009). What complexity assessments can tell us about projects: dialogue between conception and perception. *Technology Analysis and Strategic Management*, 21(5), 665–678. https://doi.org/10.1080/09537320902969208.

Geraldi, J., Maylor, H., & Williams, T. (2011). Now, let's make it really complex (complicated): A systematic review of the complexities of projects. *International Journal of Operations & Production Management*, 31(9), 966–990. https://doi.org/10.1108/01443571111165848.

Geraldi, J.G., & Adlbrecht, G. (2007). On faith, fact, and interaction in projects. *Project Management Journal*, 38(1), 32–43. https://doi.org/10.1177/875697280703800104.

Girmscheid, G. & Brockmann, C. (2008). The inherent complexity of large scale engineering projects. *ETH Zurich*, available at: https://doi.org/10.3929/ETHZ-A-005994701.

Glaser, B. G. (1978). *Theoretical sensitivity*, Sociology Press, Mill Valley, CA.

Glaser, B. G. (1992). *Basics of grounded theory analysis: Emergence vs forcing*, Sociology Press, Mill Valley, CA.

Glaser, B. G. (1998). *Doing grounded theory: Issues and discussions.* Sociology Press, Mill Valley, CA.

Glaser, B. G. (2002). Conceptualization: On Theory and Theorizing Using Grounded Theory. *International Journal of Qualitative Methods*, 1(2), 23–38. https://doi.org/10.1177/160940690200100203.

Glaser, B. G. (2005). *The grounded theory perspective III: Theoretical coding.* Sociology Press, Mill Valley, CA.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*, Aldine De Gruyter, New York, NY.

Goulding, C. (2005). Grounded theory, ethnography and phenomenology. *Journal* *of Marketing*, 39(3/4), 294–308. https://doi.org/10.1108/03090560510581782.

Gransberg, D. D., Shane, J. S., Strong, K., & del Puerto, C. L. (2013). Project Complexity Mapping in Five Dimensions for Complex Transportation Projects. *Journal of Management in Engineering*, 29(4), 316–326. https://doi.org/10.1061/(asce)me.1943-5479.0000163.

Gransberg, D., Scheepbouwer, E., & Del Puerto, C.L. (2016). Making the business case for alliance contracting on US megaprojects. *Construction Research Congress 2016*. https://doi.org/10.1061/9780784479827.040.

Haidar, A., & Ellis, R. (2010). Analysis and improvement of mega-projects performance. *Engineering Project Organizations Conference,* Tahoe, California, United States.

Hartman, F., & Ashrafi, R. (2004). Development of the SMARTTM Project Planning framework. International *Journal of Project Management,* 22(6), 499–510. https://doi.org/10.1016/j.ijproman.2003.12.003.

Hass, K.B. (2009). *Managing complex projects: A new model.* Management Concepts. Vienna, VA, USA.

Hatch, M.J., & Cunliffe, A.L. (2012). *Organization theory: modern, symbolic and postmodern perspectives*. Oxford University Press.

He, Q., Luo, L., Hu, Y., & Chan, A.P.C. (2015). Measuring the complexity of mega construction projects in China–A fuzzy analytic network process analysis. *International Journal of Project Management*, 33(3), 549–563. https://doi.org/10.1016/j.ijproman.2014.07.009.

Hertogh, J.C.M., & Westerveld, E. (2010). Playing with complexity: Management and organisation of large infrastructural projects. Erasmus University Rotterdam. Retrieved from http://hdl.handle.net/1765/18456.

Hobday, M. (1998). Product complexity, innovation and industrial organization. *Research Policy*, 26(6), 689–710. https://doi.org/10.1016/S0048-7333(97)00044-9.

Hu, Y., Chan, A.P.C., Le, Y., & Jin, R.Z. (2015). From construction megaproject management to complex project management: Bibliographic analysis. *Journal of Management in Engineering*, 31 (4), 04014052. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000254.

Hu, Y., Chan, A.P.C., Le, Y., Xu, Y., & Shan, M. (2016). Developing a program organization performance index for delivering construction megaprojects in China: Fuzzy synthetic evaluation analysis. *Journal of Management in Engineering*, 32(4), 05016007. https://doi.org/10.1061/(asce)me.1943-5479.0000432.

Hu, Y., Le, Y., Gao, X., Li, Y., & Liu, M. (2018). Grasping institutional complexity in infrastructure megaprojects through the multi-level governance system: A case study of the Hong Kong-Zhuhai-Macao Bridge construction. *Frontiers of Engineering Management*, 5(1), 52-63. https://doi.org/10.15302/J-FEM-2018074.

Hutchison, A. J., Johnston, L. H., & Breckon, J. D. (2010). Using QSR-NVivo to facilitate the development of a grounded theory project: an account of a worked example. *International Journal of Social Research Methodology*, 13(4), 283–302. https://doi.org/10.1080/13645570902996301.

Jaafari, A. (2003). Project management in the age of complexity and change. *Project Management Journal*, 34(4), 47–57. https://doi.org/10.1177/875697280303400407.

Jensen, A., & Aven, T. (2018). A new definition of complexity in a risk analysis setting. *Reliability Engineering & System Safety*, 171, 169–173. https://doi.org/10.1016/j.ress.2017.11.018.

Jones, R., & Noble, G. I. (2007). Grounded theory and management research: a lack of integrity?. *Qualitative Research in Organizations and Management*, 2 (2), 84-103. https://doi.org/10.1108/17465640710778502.

Kaimann, R.A. (1974). Coefficient of network complexity. *Management Science*, 21 (2), 172–177. https://doi.org/10.1287/mnsc.21.2.172.

Kardes, I., Ozturk, A., Cavusgil, S.T., & Cavusgil, E. (2013). Managing global megaprojects: Complexity and risk management. *International Business Review*, 22(6), 905–917. https://doi.org/10.1016/j.ibusrev.2013.01.003.

Kermanshachi, S., Dao, B., Shane, J., & Anderson, S. (2016). An Empirical Study into Identifying Project Complexity Management Strategies. *Procedia Engineering*, 145, 603–610. https://doi.org/10.1016/j.proeng.2016.04.050.

Kiridena, S., & Sense, A. (2016). Profiling Project Complexity: Insights from Complexity Science and Project Management Literature. *Project Management Journal*, 47(6), 56–74. https://doi.org/10.1177/875697281604700605.

Kolltveit, B.J., & Grønhaug, K. (2004). The importance of the early phase: The case of construction and building projects. *International Journal of Project Management*, 22(7), 545–551. https://doi.org/10.1016/j.ijproman.2004.03.002.

Koppenjan, J., Veeneman, W., van der Voort, H., ten Heuvelhof, E., & Leijten, M. (2011). Competing management approaches in large engineering projects: The Dutch RandstadRail project. *International Journal of Project Management*, 29(6), 740–750. https://doi.org/10.1016/j.ijproman.2010.07.003.

Langley, A. (1999). Strategies for Theorizing from Process Data. *The Academy of Management Review*, 24(4), 691-710. Retrieved March 24, 2021, from http://www.jstor.org/stable/259349.

Lee, G., & Xia, W. 2002. Development of a measure to assess the complexity of information systems development projects. *International Conference on Information Systems.*

Levitt, R. E., & Scott, W. R. (2017). *Institutional challenges and solutions for megaprojects.* In Flyvbjerg, B. (Ed.), The Oxford handbook of megaproject management, Oxford, UK, Oxford University Press, 96–117.

Little, T. (2005). Context-adaptive agility: Managing complexity and uncertainty. *IEEE Software*, 22(3), 28–35. https://doi.org/10.1109/MS.2005.60.

Locke, K. (2001). *Grounded theory in management research*. SAGE Publications, London.

Lu, Y., Luo, L., Wang, H., Le, Y., & Shi, Q. (2015). Measurement Model of Project Complexity for Large-Scale Projects from Task and Organization Perspective. *International Journal of Project Management*, 33(2), 610–622. https://doi.org/10.1016/j.ijproman.2014.12.005.

Luo, L., He, Q., Xie, J., Yang, D., & Wu, G. (2017). Investigating the relationship between project complexity and success in complex construction projects.

Journal of Management in Engineering, 33(2), 04016036. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000471.

Ma, H., Zeng, S., Lin, H., Chen, H., & Shi, J. J. (2017). The societal governance of megaproject social responsibility. *International Journal of Project Management*, 35(7), 1365-1377. https://doi.org/10.1016/j.ijproman.2017.01.012.

Ma, L., & Fu, H. (2020). Exploring the influence of project complexity on the mega construction project success: a qualitative comparative analysis (QCA) method. *Engineering, Construction and Architectural Management*, 27(9), 2429–2449. https://doi.org/10.1108/ECAM-12-2019-0679.

Maier, M.W. (1998). Architecting principles for systems-of-systems. *Systems Engineering*, 1(4), 267–284. https://doi.org/10.1002/(SICI)1520-6858(1998)1:4%3C267::AID-SYS3%3E3.0.CO;2-D.

Manson, S.M. (2001). Simplifying complexity: A review of complexity theory. *Geoforum*, 32(3), 405–414. https://doi.org/10.1016/S0016-7185(00)00035-X.

Mansourian, Y. (2006). Adoption of grounded theory in LIS research. *New Library World*, 107(9/10), 386–402. https://doi.org/10.1108/03074800610702589.

Maylor, H., & Turner, N. (2017). Understand, reduce, respond: project complexity management theory and practice. *International Journal of Operations & Production Management*, 37(8), 1076–1093. https://doi.org/10.1108/IJOPM-05-2016-0263.

Maylor, H., Vidgen, R., & Carver, S. (2008). Managerial complexity in project-based operations: A grounded model and its implications for practice. *Project*

Management Journal, 39(1), 15–26. https://doi.org/10.1002/pmj.20057.

Merriam-Webster. (n.d.). Complexity. In *Merriam-Webster.com* dictionary. Retrieved March 24, 2021, from https://www.merriam-webster.com/dictionary/complexity.

Merrow, E.W. (2011). *Industrial Megaprojects: Concepts, strategies, and practices for success*. John Wiley & Sons, Inc.

Mihm, J., Loch, C., & Huchzermeier, A. (2003). Problem-solving oscillations in complex engineering projects. *Management Science*, 49(6), 733–750. https://doi.org/10.1287/mnsc.49.6.733.16021.

Mikkelsen, M.F. (2020). Perceived project complexity: a survey among practitioners of project management. *International Journal of Managing Projects in Business*, Vol. ahead-of-print No. ahead-of-print, available at: https://doi.org/10.1108/ijmpb-03-2020-0095.

Miller, R., & Lessard, D. R. (2001). The Strategic Management of Large Engineering Projects. *The MIT Press*. https://doi.org/10.7551/mitpress/6478.001.0001.

Mills, J., Bonner, A., & Francis, K. (2006). Adopting a constructivist approach to grounded theory: Implications for research design. *International Journal of Nursing Practice*, 12(1), 8–13. https://doi.org/10.1111/j.1440-172x.2006.00543.x.

Mirza, E., & Ehsan, N. (2016). Development of project execution complexity index. *Journal of Engineering and Applied Sciences*, 35(1), 1-12.

Mišić, S., & Radujković, M. (2015). Critical Drivers of Megaprojects Success and Failure. *Procedia Engineering*, 122, 71-80. https://doi.org/10.1016/j.proeng.2015.10.009.

Montequín, V.R., Balsera, J.V., Fernández, S.M.C., & Fernández, F.O. (2018). Exploring project complexity through project failure factors: Analysis of cluster patterns using self-organizing maps. *Complexity*, 2018, 1–17. https://doi.org/10.1155/2018/9496731.

Müller, R., & Turner, J.R. (2007). Matching the project manager's leadership style to project type. *International Journal of Project Management*, 25(1), 21–32. https://doi.org/10.1016/j.ijproman.2006.04.003.

Nassar, K.M., & Hegab, M.Y. (2006). Developing a complexity measure for schedules. *Journal of Construction Engineering and Management*. 132 (6), 554–561. https://doi.org/10.1061/(ASCE)0733-9364(2006)132:6(554).

Nguyen, A.T., Nguyen, L.D., Le-Hoai, L., & Dang, C.N. (2015). Quantifying the complexity of transportation projects using the fuzzy analytic hierarchy process. *International Journal of Project Management*, 33(6), 1364–1376. https://doi.org/10.1016/j.ijproman.2015.02.007.

Pitsis, A., Clegg, S., Freeder, D., Sankaran, S., & Burdon, S. (2018). Megaprojects redefined – complexity vs cost and social imperatives. *International Journal of Managing Projects in Business*, 11(1), 7–34. https://doi.org/10.1108/IJMPB-07-2017-0080.

Poveda-Bautista, R., Diego-Mas, J.-A., & Leon-Medina, D. (2018). Measuring the Project Management Complexity: The Case of Information Technology Projects. *Complexity*, 2018, 1–19. https://doi.org/10.1155/2018/6058480

Prencipe, A., & Tell, F. (2001). Inter-project learning: processes and outcomes of knowledge codification in project-based firms. *Research Policy*, 30(9), 1373–

1394. https://doi.org/10.1016/S0048-7333(01)00157-3.

QSR International. (n.d.). Retrieved March 24, 2021, from https://help-nv.qsrinternational.com/12/win/v12.1.99-d3ea61/Content/concepts-strategies/using-nvivo-for-qualitative-research.htm.

Qureshi, S.M., & Kang, C. (2015). Analysing the organizational factors of project complexity using structural equation modelling. *International Journal of Project Management*, 33(1), 165–176. https://doi.org/10.1016/j.ijproman.2014.04.006.

Remington, K., Zolin, R., & Turner, R. (2009). A model of project complexity: Distinguishing dimensions of complexity from severity. *Proceedings of the 9th International Research Network of Project Management*, Berlin, 11–13.

Ribbers, P.M.A., & Schoo, K.C. (2002). Program management and complexity of ERP implementations. *Engineering Management Journal*, 14(2), 45–52. https://doi.org/10.1080/10429247.2002.11415162.

Ritchie, J. & Spencer, L. (2002). Qualitative Data Analysis for Applied Policy Research. *The Qualitative Researcher's Companion*, 305–329, SAGE Publications, Inc. https://doi.org/10.4135/9781412986274.n12.

Sbragia, R. (2000). The interface between project managers and functional managers in matrix organized product development projects. *Proceedings of the 9th International Conference on Management of Technolgy*, University of Miami, Miami.

Shenhar, A.J., & Dvir, D. (1996). Toward a typological theory of project management. *Research Policy*, 25(4), 607–632. https://doi.org/10.1016/0048-

7333(95)00877-2.

Shenhar, A.J., & Dvir, D. (2007). *How projects differ and what to do about it*. In Morris, P.W.G. and Pinto, J.A. (Ed.s), The Resource Book on the Management of Projects, John Wiley & Sons, Inc., New York, 1265–1286. https://doi.org/10.1002/9780470172391.ch50.

Sommer, S.C., & Loch, C.H. (2004). Selectionism and learning in projects with complexity and unforeseeable uncertainty. *Management Science,* 50(10), 1334–1347. https://doi.org/10.1287/mnsc.1040.0274.

Stratigea, A., Grammatikogiannis, E., & Giaoutzi, M. (2012). How to approach narratives in foresight studies: qualitative data analysis. *International Journal of Foresight and Innovation Policy*, 8(2/3), 236–261. https://doi.org/10.1504/ijfip.2012.046112.

Strauss, A. L. (1987). *Qualitative analysis for social scientists.* Cambridge University Press, New York, NY.

Strauss, A., & Corbin, J. (1990) *Basics of qualitative research: Grounded theory procedures and Techniques,* Newbury. SAGE Publications, London.

Strauss, A., & Corbin, J. (1998). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*. Sage Publications, Thousand Oaks, CA.

Tatikonda, M. V. (1999). An empirical study of platform and derivative product development projects. *Journal of Product Innovation Management*, 16(1), 3–26. https://doi.org/10.1016/s0737-6782(98)00038-1.

Tatikonda, M.V., & Rosenthal, S.R. (2000). Technology novelty, project complexity, and product development project execution success: a deeper look at task uncertainty in product innovation. *IEEE Transactions on Engineering Management*, 47(1), 74–87. https://doi.org/10.1109/17.820727.

Temperley, H.N.V. (1982). *Graph Theory and Applications.* John Wiley & Sons, Somerset, NJ, USA.

Thomas, J., & Mengel, T. (2008). Preparing project managers to deal with complexity – Advanced project management education. *International Journal of Project Management*, 26(3), 304–315. https://doi.org/10.1016/j.ijproman.2008.01.001.

Thomé, A.M.T., Scavarda, L.F., Scavarda, A., & Thomé, F.E.S. de S. (2016). Similarities and contrasts of complexity, uncertainty, risks, and resilience in supply chains and temporary multi-organization projects. *International Journal of Project Management*, 34(7), 1328–1346. https://doi.org/10.1016/j.ijproman.2015.10.012.

Thompson, J.D. (1967). *Organization in action.* McGraw-Hill, New York.

Turner, J.R., & Cochrane, R.A. (1993). Goals-and-methods matrix: coping with projects with ill defined goals and/or methods of achieving them. *International Journal of Project Management*, 11(2), 93–102. https://doi.org/10.1016/0263-7863(93)90017-H.

Valle, V. (2000). *Chaos, complexity and deterrence*, National War College, Washington, DC.

van Marrewijk, A. (2017). The Multivocality of Symbols: A longitudinal study of the Symbolic Dimensions of the Dutch High Speed Train Megaproject. *Project*

Management Journal, 48(6), 47-59. https://doi.org/10.1177/875697281704800605.

van Marrewijk, A., & Smits, K. (2016). Cultural practices of governance in the Panama Canal expansion megaproject. *International Journal of Project Management,* 34(3), 533–544. https://doi.org/10.1016/j.ijproman.2015.07.004.

van Marrewijk, A., Clegg, S.R., Pitsis, T.S., & Veenswijk, M. (2008). Managing public–private megaprojects: Paradoxes, complexity, and project design. *International Journal of Project Management*, 26(6), 591–600. https://doi.org/10.1016/j.ijproman.2007.09.007.

Vidal, L., & Marle, F. (2008). Understanding project complexity: Implications on project management. *Kybernetes*, 37(8), 1094–1110. https://doi.org/10.1108/03684920810884928.

Vidal, L.A., Marle, F., & Bocquet, J.C. (2011a). Measuring project complexity using the Analytic Hierarchy Process. *International Journal of Project Management,* 29(6), 718–727. https://doi.org/10.1016/j.ijproman.2010.07.005.

Vidal, L.A., Marle, F., & Bocquet, J.C. (2011b). Using a Delphi process and the Analytic Hierarchy Process (AHP) to evaluate the complexity of projects. *Expert Systems with Applications*, 38(5), 5388–5405. https://doi.org/10.1016/j.eswa.2010.10.016.

Waldrop, M. M. (1992). *Complexity: The emerging science at the edge of order and chaos.* Penguin, London.

Weaver, W. (1991). Science and Complexity. *Facets of Systems Science*, 7, 449–456. https://doi.org/10.1007/978-1-4899-0718-9_30.

Weitzman, (2000). *Software and Qualitative Research.* In Denzin, N.K. & Lincoln, Y.S., Handbook of qualitative research, 803-820, Sage Publications, London.

Whitty, S.J., & Maylor, H. (2009). And then came complex project management (revised). *International Journal of Project Management*, 27(3), 304–310. https://doi.org/10.1016/j.ijproman.2008.03.004.

Williams, T. M. (2005). Assessing and moving on from the dominant project management discourse in the light of project overruns. *IEEE Transactions on Engineering Management*, 52(4), 497–508. https://doi.org/10.1109/tem.2005.856572.

Williams, T.M. (1999). The need for new paradigms for complex projects. *International Journal of Project Management*, 17(5), 269–273. https://doi.org/10.1016/S0263-7863(98)00047-7.

Williams, T.M. (2002). *Modelling complex projects.* Wiley, London.

Wood, H., & Ashton, P. (2010). The factors of project complexity. *Proc., TG62—Special Track, 18th CIB World Building Congress*, CIB Publication, Rotterdam, Netherlands.

Wu, G., Zhao, X., & Zuo, J. (2018). Effects of inter-organizational conflicts on construction project added value in China. *International Journal of Conflict Management*, 28(5), 695-723. https://doi.org/10.1108/ijcma-03-2017-0025.

Xia, B., & Chan, A.P.C. (2012). Measuring complexity for building projects: a Delphi study. *Engineering, Construction and Architectural Management*, 19(1), 7–24. https://doi.org/10.1108/09699981211192544.

Xia, W., & Lee, G. (2004). Grasping the complexity of IS development projects.

Communications of the ACM, 47(5), 68–74. https://doi.org/10.1145/986213.986215.

Zhai, L., Xin, Y., & Cheng, C. (2009). Understanding the value of project management from a stakeholder's perspective: Case study of mega-project management. *Project Management Journal*, 40(1), 99–109. https://doi.org/10.1002/pmj.20099.

Zhu, J., & Mostafavi, A. (2017). Discovering complexity and emergent properties in project systems: A new approach to understanding project performance. *International Journal of Project Management*, 35(1), 1–12. https://doi.org/10.1016/j.ijproman.2016.10.004.

Zidane, Y. J-T, Anandasivakumar, E., & Johansen, A. (2012). An overall framework for understanding changes in megaprojects – a Norwegian approach. *26th IPMA World Congress*, Crete, Greece.

APPENDICES

A. Project Complexity Literature Review (Bakhshi et al., 2016)

Table A.1 Project complexity factors based on systematic literature review (Bakhshi et al., 2016)

Dimension	Project complexity factors (provenance of complexity)	Number of referred	Referred to by
Context	Unusual type of design process	9	Akintoye (2000), Austin et al. (2002), Azim (2010), Baccarini, 1996, Bosch-Rekveldt et al. (2011), Calinescu et al. (1998), Cicmil et al. (2006), Crawford (2005), Fang and Marle (2013), Favari (2012), Frame (2002), Geraldi and Adlbrecht (2007), Geraldi (2008), Gidado (1996), Hussein et al. (2013), Hussein (2012), Koivu et al. (2004), Lessard et al. (2014), Leung Wing Tak (2007), Little and Graphics (2005), Maylor et al. (2008), Müller et al. (2007), Qing-hua et al. (2012), Qureshi and Kang (2014), Remington et al. (2009), Saynisch (2010b), Senescu et al. (2013), Sinha et al. (2006), Vidal et al. (2011a), Vidal and Marle (2008), Wood and Gidado (2008), Xia and Chan (2012), Xia and Lee (2004)
	Demand of creativity	9	
	Scope for development	7	
	Institutional configuration	10	
	Significant on public agenda	9	
	Degree of project flexibility (in scope, process, organisation…)	9	
	HSSE issues	7	
	Decision making process challenges	8	
	Repetition of similar type of projects	7	
	Internal politics issue (ambiguity, hidden information)	12	
	Environment complexity (networked environment)	13	
	Cultural configuration	19	
	Form of contract	10	
	Overlapping office hours	6	
	Stability project environment	4	
	Experience with parties involved	5	
	Project drive	7	
	Commercial newness of the project (new partners, teams etc.)	9	
	Conflict between stakeholders	7	
	Level of competition between stakeholders	12	
	Lack of support (top management, users, staff members etc.)	7	
	Organisational degree of innovation	10	
	New laws and regulations	11	
	Local laws and regulations	16	
	Level of competition	12	
	Environment of changing technology, economy and nature	11	
	Functional role	7	
	Degree of obtaining information	5	
	Interaction between the technology system and external environment	5	
	Organisational risks	7	

Table A.1 (Cont'd) Project complexity factors based on systematic literature review (Bakhshi et al., 2016)

Dimension	Project complexity factors (provenance of complexity)	Number of referred	Referred to by
	Neighbouring environment (including the site access/location)	9	
	Geological condition/difficulty of location	13	
	External politics issue	9	
	Union power	7	
Belonging	Quality requirements	8	Alderman and Ivory (2007), Antoniadis et al. (2011), Azim (2010), Baccarini (1996), Bosch-Rekveldt et al. (2011), Camci and Kotnour (2006), Castejón-Limas et al. (2010), Cicmil and Marshall (2005), Fang and Marle (2013), Geraldi and Adlbrecht (2007), Gidado (1996), Hussein et al. (2013), Hobday (1998), Hussein (2012), Little and Graphics (2005), Maylor et al. (2008), Qureshi and Kang (2014), Ramasesh and Browning (2014), Remington et al. (2009), Shenhar et al. (2004); Tatikonda (1999), Vidal et al. (2007, 2011b), Vidal and Marle (2008), Xia and Chan (2012), Xia and Lee (2004), Yugue and Maximiano (2012)
	Cost restraints (cost and financing)	9	
	Specific requirements/standards	13	
	Capability (knowledge, experience, education, training etc.)	11	
	Technical capability of team	10	
	Unknown/poorly defined requirements	10	
	Bespoke software or hardware	1	
	Trust in stakeholders	13	
	Team transparency, empathy (the personal and intangible matter that improves cooperation)	8	
	Project Manager competencies	9	
	Technological degree of innovation	12	
	Risk of highly difficult technology	9	
	Technological newness of the project	17	
	Highly customised products	2	
	Responsibility & Accountability	8	
	Requirements capture	3	
Autonomy	Availability of people, material and of any resources due to sharing	16	Antoniadis et al. (2011), Azim (2010), Baccarini (1996), Bosch-Rekveldt et al. (2011), Browning (2014), Cicmil and Marshall (2005), Favari (2012), Geraldi and Adlbrecht (2007), Gidado (1996), Green (2004), Hussein et al. (2013), Kennedy et al. (2011), Lessard et al. (2014), Little and Graphics (2005), Lu et al. (2015), Maier (1996), Maylor et al. (2008), Pich et al. (2002), Qureshi and Kang (2014),
	Level of interrelation of between phases	9	
	Team/partner cooperation and communication	22	
	Levels of management are involved in project decision-making	5	
	The amount of overlap and interactions	11	
	Dynamic and evolving team structure	12	
	Dependencies with the environment	12	
	Interdependencies between sites, departments and companies	19	
	Interdependencies of objectives/interests	16	

Table A.1 (Cont'd) Project complexity factors based on systematic literature review (Bakhshi et al., 2016)

Dimension	Project complexity factors (provenance of complexity)	Number of referred	Referred to by
	Process interdependence	15	Remington et al. (2009), Senescu et al. (2013), Sinha et al. (2006), Tatikonda and Rosenthal (2000), Thomas and Mengel (2008), Vidal et al. (2007, 2011a, 2011b), Vidal and Marle (2008), Williams (1999), Wood and Gidado (2008), Xia and Chan (2012), Yugue and Maximiano (2012)
	Stakeholders interrelation/interdependencies	12	
	Interdependencies between actors	13	
	Specifications interdependence	10	
	Interdependence between components of the product	5	
	Technological process dependencies	14	
	Resource and raw material interdependence	10	
	Dependencies between schedules	13	
	Interdependencies of information systems	11	
	Number of governmental people who involved in projects	7	
	Combined transportation	9	
Connectivity	Interconnectivity and feedback loops in the task and project networks	16	Bosch-Rekveldt et al. (2011) Favari (2012), Gidado (1996), Green (2004), Kennedy et al. (2011), Lessard et al. (2014), Lu et al. (2015), Qing-hua et al. (2012), Qureshi and Kang (2014), Ramasesh and Browning (2014), Vidal et al. (2011a), Vidal and Marle (2008), Williams (1999)
	Face to face relationship between project team members	4	
	Number of interfaces in the project organisation	9	
	Relations with permanent organisations	10	
	Capacity of transferring information	5	
	Level of processing information	5	
	Goals/interests alignment	16	
Emergence	Dynamics of the task activities	8	Akintoye (2000), Azim (2010), Ahern et al. (2014), Bosch-Rekveldt et al. (2011), Brady et al. (2012), Crawford (2005), Geraldi and Adlbrecht (2007), Geraldi et al. (2011), Jaafari (2001), McDaniel and Driebe (2001), Little and Graphics (2005), Maylor et al. (2008), Müller et al. (2007); Ramasesh and Browning, 2014; Senescu et al. (2013), Shenhar (2001b), Turner and Cochrane (1993), Vidal et al. (2011a), Vidal and Marle (2008), Wood and Gidado (2008), Yugue and Maximiano (2012)
	Uncertainties of scope	18	
	Uncertainty & clarity of objectives or goals	17	
	Uncertainty in technical methods	16	
	Information uncertainty	10	
	Clients with unrealistic goals	7	
	Market uncertainty	5	

Table A.1 (Cont'd) Project complexity factors based on systematic literature review (Bakhshi et al., 2016)

Dimension	Project complexity factors (provenance of complexity)	Number of referred	Referred to by
Diversity	Variety of financial resources	14	Akintoye (2000), Azim (2010), Baccarini (1996), Bosch-Rekveldt et al. (2011), Brady and Davies (2014), Camci and Kotnour (2006), Castejón-Limas et al. (2010), Cicmil and Marshall (2005), Frame (2002), Geraldi and Adlbrecht (2007), Gidado (1996), Green (2004), Hobday (1998), Hussein (2012), Lessard et al. (2014), Maier (1996), Maylor et al. (2008), Müller and Turner (2007), Qing-hua et al. (2012), Qureshi and Kang (2014), Ramasesh and Browning (2014), Remington et al. (2009), Santana (1990), Sinha et al. (2006), Thomas and Mengel (2008), Vidal et al. (2007, 2011a, 2011b), Vidal and Marle (2008), Williams (1999), Wood and Gidado (2008), Xia and Chan (2012), Xia and Lee (2004), Yugue and Maximiano (2012)
	Variety of organisational skills needed	13	
	Variety of the project management methods and tools applied	18	
	Variety of resources to be manipulated	10	
	Diversity of tasks	11	
	Diversity of inputs and/or outputs	9	
	Variety of the interests of the stakeholders	18	
	Diversity of staff (experience, social span …)	13	
	Variety of the stakeholders status	10	
	Cultural variety	19	
	Number of different languages	10	
	Multiple time zones	5	
	Variety of hierarchical levels within the organisation	11	
	Variety of organisational interdependencies	16	
	Variety of technological dependencies	13	
	Variety of the technologies used during the project	12	
	Variety of technological skills needed	16	
	Multiple participating countries/location	13	
	Geographic location of the stakeholders	12	
	Variety of information systems to be combined	11	
	Variety of the product components	10	
	Client transparency, empathy (the personal and intangible matter that improves cooperation)	12	
	Multiple suppliers, contractors, vendors, etc.	8	
Size	Number of decisions to be made	10	Akintoye (2000), Azim (2010), Baccarini (1996), Bosch-Rekveldt et al. (2011), Camci and Kotnour (2006), Castejón-Limas et al. (2010), Cicmil and Marshall (2005), Crawford (2005), Doyle and Hughes (2000), De Reyck and Herroelen (1996), Frame (2002), Geraldi and Adlbrecht (2007),
	Duration of the project	18	
	Number of deliverables/disciplines	17	
	Number and quantity of resources	12	
	Number of activities	15	
	Largeness of capital investment	11	
	Number of the project management methods and tools applied	18	
	Number of different occupational specialisations	5	
	Number of inputs and/or outputs	9	

Table A.1 (Cont'd) Project complexity factors based on systematic literature review (Bakhshi et al., 2016)

Dimension	Project complexity factors (provenance of complexity)	Number of referred	Referred to by
	Largeness of scope (number of components etc.)	18	Gidado (1996), Giezen (2012), Green (2004), Hussein (2012), Lessard et al. (2014), Leung Wing Tak (2007), Maylor et al. (2008), Müller and Turner (2007), Nassar and Hegab (2006), Qureshi and Kang (2014), Ramasesh and Browning (2014), Remington et al. (2009), Santana (1990), Shenhar et al. (1995), Shenhar (2001a), Sinha et al. (2006), Thomas and Mengel (2008), Vidal et al. (2007, 2011a, 2011b), Vidal and Marle (2008), Williams (1999), Wood and Gidado (2008), Xia and Chan (2012), Xia and Lee (2004), Yugue and Maximiano (2012)
	Size in CAPEX (Capital expenditures)	7	
	Number of stakeholders	23	
	Number of companies/projects sharing their resources	16	
	Number of formal units & departments involved	22	
	Number of objectives	14	
	Number of investors	12	
	Staff quantity	10	
	Number of structures/groups/teams to be coordinated	25	
	Number of hierarchical levels	14	
	Number of information systems	13	