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Complexity Management in Large Construction Projects: Identifying Factors and Variables

Büyük İnşaat Projelerinde Karmaşıklık Yönetimi: Faktörlerin ve Değişkenlerin Belirlenmesi

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ABSTRACT

This study answers the questions "what are the main factors of complexity in large projects?" and "what kind of relationships are there among the factors?" To answer these questions, the purpose of this research is identifying the factors of project complexity in the large construction and the relationships among them. Structural, technological, and environmental complexities considered as the main themes, and they formed the main components of the conceptual model. Research strategy is multiple case study in Iranian large construction projects, and research method is survey. The project experts of the selected cases form the research population, and stratified sampling method is the sample selection method. Accordingly, 300 questionnaires were distributed among the members, and finally 120 completed questionnaires were analyzed using structural modeling. The findings indicate that there is a significant relationship between environmental complexity and project complexity. That is, when the complexity of the project environment, including economic, social, and political factors, raise, the complexity of the project increases too, while both technological and structural complexities at the 0.001 level affect project complexity less than environmental factos. In other words, the relationships between technological and structural complexities with project complexity in Iranian large projects are weaker than environmental complexity. So, the intensity of the relationship between the last two factors is slightly different with the literature.

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Anahtar Kelimeler:

Karmaşıklık,

Proje Karmaşıklığı,

Teknolojik - Çevresel ve Yapısal Karmaşıklık,

ÖZET

Bu çalışma, "büyük projelerde karmaşıklığın ana faktörleri nelerdir?" ve "aralarında ne tür ilişkiler vardır?" sorularına cevap vermektedir. Bu çalışmanın temel amacı, büyük inşaat alanlarında proje karmaşıklığının faktörlerini ve ilişkilerini belirlemektir. Yapısal, teknolojik ve çevresel karmaşıklıklar ana temalar olarak ele alınmış ve kavramsal modelin ana bileşenlerini oluşturmuştur. Araştırma stratejisi, İran'daki büyük inşaat projelerinde çoklu vaka çalışmasıdır ve araştırma yöntemi ankettir. Seçilen vakaların proje uzmanları araştırma evrenini oluşturur ve tabakalı örnekleme yöntemi örneklem seçim yöntemidir. Araştırma popülasyonuna 300 anket dağıtılmış ve son olarak 120 tamamlanmış anket yapısal modelleme kullanılarak analiz edilmiştir. Bulgular, çevresel karmaşıklık ile proje karmaşıklığı arasında önemli bir ilişki olduğunu göstermektedir. Yani ekonomik, sosyal ve politik faktörler dâhil olmak üzere proje ortamının karmaşıklığı arttığında, projenin de karmaşıklığı artarken, 0.001 düzeyindeki hem teknolojik, hem de yapısal karmaşıklıklar proje karmaşıklığını çevreselden daha az etkilemiştir. Başka bir deyişle, İran'ın büyük projelerinde teknolojik ve yapısal karmaşıklıklar ile proje karmaşıklığı arasındaki ilişki çevresel karmaşıklıktan daha zayıftır. Dolayısıyla, son iki faktör arasındaki ilişkinin yoğunluğu literatürden biraz farklıdır.

1. INTRODUCTION

Today, large projects play an important role in the economy and budgeting system of countries (Prasad and Vasugi, 2017). The share of the construction projects in Iran, for instance, despite the recession, was 5,6% of GDP in 2020 while it was $154.4 billion in 2016. France, Canada, and the US, also, were reported the rate at 6,80% in 2021, 7,5% in 2019, and 5,66% in 2017 respectively (Statista, 2022). Thus, project management of constructions, which is often large-scale and complex, and probably encounters various problems, is vital. Complexity in the projects leads to increased time and cost, and it affects project planning and control (San Cristóbal et al., 2018). In addition, the complexity can create great challenges for the project. It can hinder the clear identification of goals and objectives, it can affect the selection of an appropriate project organization form, or it can even affect project outcomes (Baccarini, 1996). On the other hand, the impact of large or mega projects on various environmental aspects of countries has been approved by experts (Flyvbjerg, 2014; Ishtiaq and Jahanzaib, 2017).

Understanding the complexity of the project and recognizing it is a major problem in project management because there is no consensus on what complexity is (Bakhshi vd., 2016). This disagreement is greater in the field of construction. Sinha, Kumar, and Thomson (2006) state that there is no single concept of complexity that convinces us exactly what it means. Remington and Pollack (2007) also noted in their research that many project managers have a different understanding of project complexity (Remington and Pollack, 2007). Most of the projects are described as simple, but their management is complex (Baccarini, 1996). So, although most large projects are complex, project size has not always been a good measure of complexity. Thus, the main problem is the lack of consensus on an acceptable approach by all project management professionals to identify and manage complexity in large projects.

In the past, PM could rely on their technical expertise and experience to make good decisions about project complexity. But today's projects are different; they often involve such intricate stakeholder interdependencies that no one can know them all. As a result, complexity management in the large projects requires creative methods. It seems that one of the best ways to identify complexity is to avoid drowning in different definitions and categorizing complexity, because not only does it not help much in understanding complexity, but it also confuses researchers, especially novice researchers. Instead, we can identify the factors and variables that cause complexity. Identifying these factors can be an important resource for managers' decisions, and the basis for a project complexity assessment system. Accordingly, the main questions that this study seeks to answer are: What are the factors that affect the complexity of large projects? And what are the relationships among the factors?

2. LITERATURE REVIEW

2.1. Definition of Project Complexity

Complexity is a challenging concept in project management. There is no consensus among experts on its meaning (Bakhshi et al., 2016). So, different definitions of it are provided, some of which are mentioned here. Baccarini (1996), as one of the first theorists of project complexity, believes that "complexity consisting of many varied interrelated parts, complicated, involved, and intricate. Girmscheid and Brockmann (2007) associate complex projects with the number of elements and with the concept of linearity. They define project complexity as "*a set of problems that consists of many parts with a multitude of possible interrelations, most of them being of high consequence in the decision-making process that brings about the final result*". On the other hand, Richardson (2008) in a study entitled *"Managing complex organizations"* associates linearity with complicated projects and nonlinearity with complex projects, which implies that nonlinearity makes the relationship between inputs and outputs unpredictable (Richardson, 2008).

Remington, Zolin, and Turner (2009) efines a complex project as one that demonstrates several characteristics to a degree or level of severity that makes it extremely difficult to predict project outcomes, to control or manage the project. In the field of construction also, there is no accepted definition among researchers. Baccarini (1996) is one of the first researchers who have written about complexity in construction projects. He believes, these projects are invariably complex, and its' process may be considered the most complex undertaking in any industry.

2.2. Classification of Project Complexity

There are different types of project complexity. Project complexity might be structural. It refers to "*the (potentially) non-linear interactions between the activities of a project*" (Gill, 2008). It also is "*the heterogeneity and irregularity levels of structural elements*" (Yanovski et al., 2017) which compose the topographic contours of a project. Gill (2008) modifies earlier models and characterizes problem space structure on three dimensions: "*state, operator, and goal*". In each dimension, there are two scales: "*one reflecting the qualitative nature of the dimension and one reflecting the degree of uncertainty or ambiguity present*" (Gill, 2008).

Thus, Structural complexity spans across several dimensions relevant to the project management process. It is where "*the project itself or the deliverable of the project has large numbers of elements, where it has large numbers of interconnections between the elements themselves within the project, large numbers of inter-related contracts or other forms of structural elements inside the project which have complex inter-relationships*" (Baccarini, 1996; Williams, 1999). Technological complexity is also common in projects. Technology refers to the "*process of converting inputs into outputs in a project*" (Baccarini, 1996) that includes "*operations (equipping and sequencing activities), materials characteristics, knowledge characteristics*" (Remington et al., 2009).

Technology therefore includes the "*physical properties, procedures, methods, and processes that make up an organizational function*" (Dooley, 2002). According to Baccarini (1996), project technological complexity comes from "*differentiation and interdependence*". Technological complexity due to differentiation "*concentrates to diversity of technologies in the project*", and the "*technological complexity due to interdependence*" refers to the degree of interdependence of technologies on each other (Baccarini, 1996).

The complexity of the project can be environmental. Every project face challenges that occur in complex project environments. The project environment is often referred to as a "*temporary organization*" where social interactions occur to deliver projects (Algeo, 2014). So, project environment represents a connection, where the project is processed. It impacts the project and is conditioned. Such an interaction is provided by numerous factors as operational, physical, ecological, social, cultural, economic, psychological, financial, organizational etc. Studies show that complexity is defined by the number, variety, and extent of interactions between environmental activities. In the absence of an efficient fit and alignment between the nature of the environment and the mechanisms within the organization, project failure is certain (Miles et al., 1974). Stephen Robbins (1998) believes that the degree of change in environmental factors affecting "*the organizations determine the degree of environmental dynamism-sustainability*".

2.3. Factors of Project Complexity

The studies in project complexity show that not all projects are complex in the same way. Therefore, there is, potentially, more than one source of complexity in a project, such as level of interconnectedness, lack of clarity of goals, means to achieve goals (i.e. technology) (Remington et al., 2009). Understanding the source of the complexity and to what degree the resultant difficulties will be played out might help us to determine the skills and capabilities needed to deal with the problem. Thus, some of the most important factors affecting the complexity of the project, both public and construction projects, are mentioned from the perspective of experts.

2.3.1. Experts' Views on the Project Complexity Factors as General

Gidado and Millar (1992) viewed project complexity in terms of *"(1) technical complexity of task, (2) amount of overlap and interdependencies in construction stages, (3) project organization, (4) site layout, and (5) unpredictability of work on site"*. Gidado (1996) identified a number of aspects of project complexity, including *"(1) the employed resources, (2) the environment, (3) the level of scientific and technological knowledge required, (4) the number of different parts in the work flow, and (5) the interaction of different parts in the work flow*" (Xia and Chan, 2012).

Vidal and Marle (2008:1097) consider the following factors as necessary but nonsufficient conditions for project complexity; *"size, variety, interdependences and interrelations within the project system, and context dependence"*. Remington et al. (2009) in research entitled "*A Model of Project Complexity*" group a number of factors that seem to contribute to the perception of project complexity under the following headings; "*goals, stakeholders, interfaces and interdependencies, technology, management process, work practices, and time"* (San Cristóbal et al., 2018).

Chan (1998:25) proposes five casual factors of project complexity; *"(1) client's attributes, (2) site condition/site access problems, (3) buildability of project design, (4) quality of design coordination and (5) quality management"*. In addition, Little (2005:29) stated complexity of projects in terms of *"group size, mission sensitivity, group location, group capacity, domain knowledge gap, and dependencies"*. According to the literature, these factors affect the complexity of the project in its general sense. According to the literature, these factors affect the complexity of the project in its general sense.

2.3.2. Experts' Views on the Project Complexity Factors as Construction Projects

Some researches have addressed the complexity of the project in the field of construction more specifically while there is no consensus in this field either. Santana (1990) classified construction projects into three categories, namely, normal, complex, and singular, according to the scale of complexity. Ten groups of variables are used for the classification, which include *"(1) owner or investor, (2) cost and financing, (3) terms of study and execution, (4) stages of project, (5) administrative and legal framework, (6) impact on natural and social environment, (7) physical location, (8) technology, (9) resources, and (10) logistics of the construction"*.

Leung (2007) in the research "*classification of building project complexity and evaluation of supervisory staffing patterns using cluster and factor analysis techniques*" built up construction complexity index (CCI) as an objective quantitative tool to measure the complexity of construction for building projects. Ten variables defining the project complexity are identified as *"(1) project duration, (2) working spaces, (3) contract sum, (4) site area, (5) type of structure, (6) height of building, (7) site location, (8) client, (9) usage of building, and (10) total floor area"* (Xia and Chan, 2012).

The literature review shows that so far there is no universally accepted approach to managing the complexity in the construction projects. In addition, traditional approaches of the complexity management, such as linearity, have disadvantages that exclude their use in PM. Also, the studies show that not all projects are complex in the same way. Therefore, there is, potentially, more than one source of complexity in a project. Literature review illustartes three main types of project complexities; structural, technological, and environmental. It seems, identifying the factors of them is an effective way to understand project complexity in construction area. So, the specific question of the research is "*What are the factors of structural, technological, and environmental complexities in large projects?*" and "*what factors have more influence than others?*" What are the relationships between technological, environmental, and structural factors? And how do they affect the complexity of the project? To answer these questions, the purpose of the research is: "*identifying the factors of structural, technological, and environmental complexities in large construction projects and determining the most effective factors, and the relationships*".

3. CONCEPTUAL FRAMEWORK AND THE RESEARCH HYPOTHESES

This research is based on deductive reasoning. Accordingly, existing theories about project complexity form the main basis of the philosophical structure of this research. Literature review shows that researchers over the past three decades have focused on a variety of concepts such as structure, technology, organization, goals, information, stakeholders, decision-making, systems, resources, environment, degree of innovation, risk and uncertainty, project teams, leadership, etc., and have been introduced them as factors of complexity. A deeper look at these concepts reveals that most of them are sub-factors that can be a subset of the three main factors of structural, technological, and environmental complexity. The number of frequencies of the extracted factors in this study confirms this issue, so that these three factors had the highest frequency in the selected articles and have been emphasized in the works of leading experts in the field of project complexity.

Structural complexity involves the scale of the work on the project (Baccarini, 1996), and it refers to the degree to which a task is performed using task specific (as opposed to general purpose) knowledge, teams, interested parties, structures, and goals (Papaioannou and Koutselini, 2007; Robbins et al., 2005). A project is structurally complex when it is large scale, it has many stakeholders, workstreams or other elements, and many professionals work in (Harrin, 2014). It is also structurally centralized and highly formalized (Robbins et al., 2005). Under a structural complexity definition, low structure is more complex than high structure, for example, unfamiliar tasks are more structurally complex than routine tasks (Gill, 2008). In addition, technology complexity, which was first proposed by Baccarini (1996) and Williams (1999), was followed by other researchers so that today it can be seen in almost all project complexity studies (Remington and Pollack, 2007; San Cristóbal et al., 2018; Vidal and Marle, 2008; Xia and Chan, 2012).

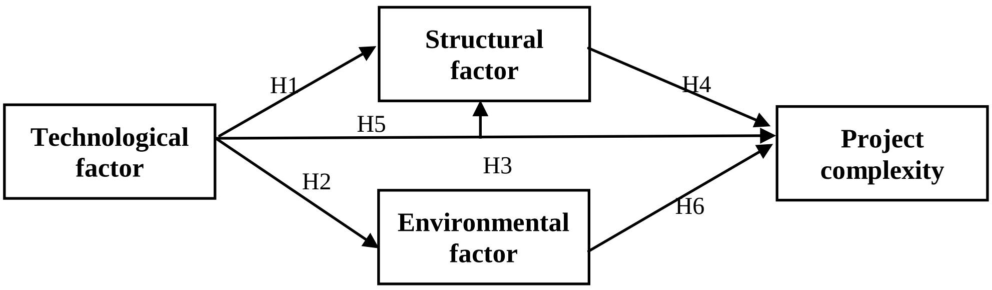
Despite its theoretical relevance and an increasing empirical interest, measuring the complexity of technologies empirically is a complicated issue, and as Tom Broekel (2017:2) note: *"We do not have any easy way to measure complexity*" (Broekel, 2017). Technological complexity by differentiation refers to the variety and diversity of some aspects of a task such as number and diversity of inputs/outputs, number, and diversity of tasks to undertake, and number of specialities and contractors, involved in the project (San Cristóbal et al., 2018). Technological complexity by interdependency encompasses interdependencies between tasks, within a network of tasks, between teams, between different technologies, and between inputs (Williams, 1999). Thus, the greater the degree of interdependence between different technologies, and between inputs, outputs, and processes, the higher the complexity of the technology.

Later Bosch-Rekveld et al. (2011) added environmental complexity to Baccarini proposal giving rise to their TOE (technological, organizational, and environmental) framework. Environmental complexity refers to the number of elements in the organization's environment and their connections. In a highly complex environment, there are many variables, like economic, social, cultural, and political that can affect the projects complexity (Saylor Academy, 2012). High scores for complexity in this category imply high risks for delay and expensive resolution to lawsuits, public opposition, changes for political considerations, and unforeseen ecological impacts (Algeo, 2014; San Cristóbal et al., 2018).

Another important consideration is the relationship between these factors and the outcome of their impact on the complexity of the project. They are well-known factors in the field of organization and management. According to Stephen Robbins (1990:173) in his book "*Organisation Theory-Structure, Design and Applications*", as well as Richard Daft (2014:88) in the entitled "*Organization Theory and Design*", technological, and environmental factors have a direct impact on structural complexity. That is, upgrading the level of technology in the organization as well as the complexity of the organization's environment will also complicate its structure.

On the other hand, technological factors also affect the environment of the organization. Complex technologies offer substantial economic benefits, and they are difficult to invent and to imitate, and they refuse a fast dissemination. So, they motivates the idea that regions' competitive advantages and, in consequence, their economic growth, originate in their ability to produce and utilize complex technologies (Mewes and Broekel, 2020). Thus, based on deductive reasoning and moving from macro theories to factors and variables, the theoretical model consisting of the mentioned complexity factors, and their relationship are shown in figure 1.

Figure 1. The Framework of the Research



As a result of reviewing the literature and considering all aspects and according to the components of the conceptual model and the relationships created in the model the research hypotheses will be as follows.

H_1: Technological complexity affects the structural complexity in large construction projects of Iran.

H_2: Technological complexity affects the environmental complexity in large construction projects of Iran.

H_3: Environmental complexity affects the structural complexity in large construction projects of Iran.

H_4: Structural complexity affects the project complexity in large construction projects of Iran.

H_5: Technological complexity affects the project complexity in large construction projects of Iran.

H_6: Environmental complexity affects the project complexity in large construction projects of Iran.

4. RESEARCH METHODOLOGY

The main purpose of this study is to identify the factors and variables of project complexity that can be a basis for assessing the complexity of the project in the field of construction. Since based on deductive reasoning these factors and variables have been identified through the literature review, first the researcher has used multiple case study strategy to seek the opinions of experts in several large projects about these factors. This strategy is consisted with research objective because the case study is an appropriate method for emerging fields of research (Bérubé and Noël, 2011), but since there is still no consensus on the project complexity literature (Bakhshi et al., 2016; San Cristóbal et al., 2018), it is necessary for the researcher to know the opinion of construction project experts on the components of the model. Therefore, in the second stage, a survey of experts in the field of project management has been conducted. So, survey is the method of research to collect data. For this purpose, A questionnaire containing 36 questions was designed which literature review and information extracted from the interviews conducted from the case study in the first stage were the basis of all the questions. Before testing the model, the validity and reliability of the questionnaire were examined.

First, internal compatibility and reliability were evaluated using Cronbach's alpha technique. The results show that the values of Cronbach’s alpha for the constructs was greater than 0.70 (Hair et al., 2017), indicating an adequate internal consistency. The table 5 shows Cronbach's alpha results for research structures. The content validity method was used to determine the validity. In this method, the validity of the measurement tool is examined through the opinions of experts. In this research, the items of the questionnaire were provided to the project management specialists several times and by applying their opinions, the final questions were approved. The population of this study includes experts and managers of public construction projects in Iran. This community has been emphasized because most public construction projects such as bridges, large buildings and towers, tunnels, etc. are large and complex projects (Brockmann and Girmscheid, 2007; Flyvbjerg, 2014) and they have important impact in macroeconomics. The conditions of time, place, and cost do not allow the study of the whole population (Bell et al., 2018).

Thus, the researcher must choose samples. In this research, stratified sampling method is used because the researcher is being sure that the members of the study population (project as case) are different in terms of characteristics and traits (Bell et al., 2018), and their views about PM strategies are different. The stratified sampling model gives the researcher a good opportunity to generalize the number of samples to all specialized groups in the cases and select a sample from each group within the case, in proportion to the number of members. Table 1 indicates the number of specialists in each project that make up the statistical population.

Table 1. Distribution of the Groups in the Projects

Project	Project Code	Design	Test / QC	Construct	Leadership	Electro-Mechanics	Networking	Population
Sadr	A	17	22	75	15	25	15	169
Pardise	B	15	17	45	14	15	15	121
Iran Mall	C	20	25	82	17	30	16	190
Tehran-Shomal	D	15	18	70	15	17	15	150
Shahr-e-jadid Hashtgerd	E	18	20	80	17	18	17	170
	Total	85	102	352	78	105	78	800

If the researcher selects 15% of the statistical population as the samples to ensure the validity of statistical tests in later stages, the number of samples (n) will be 120. Accordingly, the sample ratio of each group will be as shown in Table 2. To select the samples within each team in the next step, the researcher will use a simple random sampling method. Using this method gives all team members an equal chance to be selected as a sample.

Table 2. Sample Ratio of Each Group in the Projects

Project code	Design			Test / QC			Construction			Leadership			Electro-mechanic			Networking			Population		
A	17	0.10	3	22	0.13	3	75	0.44	11	15	0.09	2	25	0.15	4	15	0.09	2	169	0.21	25
B	15	0.12	2	17	0.14	3	45	0.37	7	14	0.12	2	15	0.12	2	15	0.12	2	121	0.15	18
C	20	0.11	3	25	0.13	4	82	0.43	12	17	0.09	3	30	0.16	5	16	0.08	2	190	0.24	29
D	15	0.10	2	18	0.12	3	70	0.47	11	15	0.10	2	17	0.11	3	15	0.10	2	150	0.19	23
E	18	0.11	3	20	0.12	3	80	0.47	12	17	0.10	3	18	0.11	3	17	0.10	3	170	0.21	26
Total	85	0.11	13	102	0.13	15	352	0.44	53	78	0.10	12	105	0.13	16	78	0.10	12	800	1.00	120

Structural equation modeling has been used to analyze the data and identify the relationships between the factors and determine the share of each of them. Structural equation modeling is a comprehensive statistical approach to test hypotheses about the relationships between observed variables and latent variables. Through this method, the acceptability of the theoretical model can be tested by the study population, and since most of the variables affecting the complexity of the project are hidden, it is necessary to use this method. For this analysis, the software Amos27 and SPSS27 were used, the report of which is presented in the next section.

5. THE FINDINGS AND DISCUSSION

5.1. General Findings

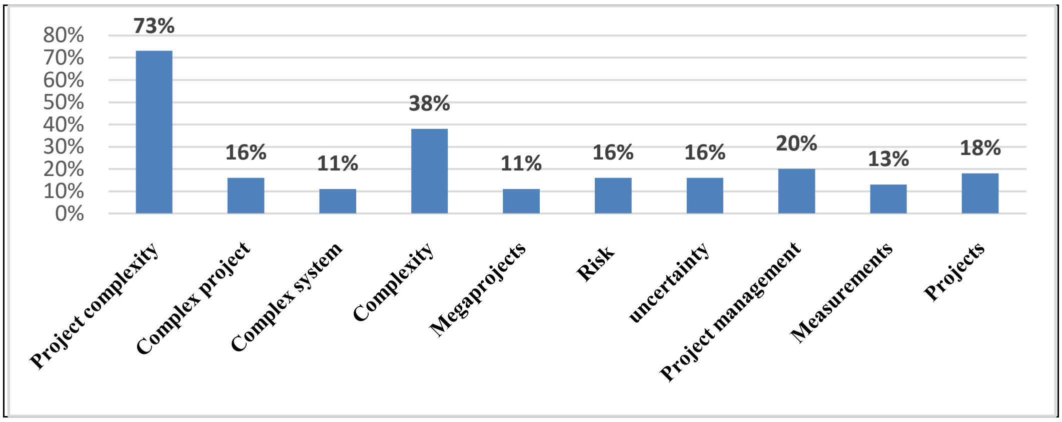
In the first part of the paper, the project complexity was examined theoretically and historically based on the articles extracted in the last three decades (from 1991 to 2020). In the first stage, articles were extracted that were like or close to the research topic. Then, all extracted articles were reviewed. Titles, abstracts, keywords, headings, conclusions, year of writing, and database were considered to review the articles. From the collection of articles, some were selected and studied in full. The purpose of a full study of these papers was to extract the following: (1) Define the complexity of the project, especially in the field of construction, (2) Identifying complex projects conceptual frameworks in construction area, and (3) Identifying the factors affecting the complexity of the project. Table 3 shows the frequency of extracted papers based on database, years, and field of concentration in the articles.

Table 3. Frequency of Extracted Articles Based on Three Items

Database/ Publication Periods and Fields		Frequency	Percentage
Database Source	Science Direct	14	62%
	Scopus	43	20%
	Intonational Journals of PM	8	11%
	Other Databases	5	7%
Publication Periods	1991-2000	13	18%
	2001-2010	23	33%
	2011-2020	34	49%
Concentrated Filed / Area	General	53	76%
	System	6	9%
	Social and Economic	3	4%
	Construction	8	11%

The entire keywords of the papers were completely extracted and listed. The purpose of the keyword review was to evaluate the similarity and closeness of the selected articles to the research topic. There were more than 25 different keywords in the articles, some of which had a frequency of 1 or 2, but others had more frequencies. Because it was not possible to show all of them in a chart, therefore, in the figure 2 was provided only the frequency more than 10%. As the figure shows, most frequencies belong to project complexity (73%). It means, most of the selected papers were relevant to the research topic, and the extracted data will be valid.

Figure 2. Frequency of Keywords Items in the Selected Papers



As mentioned, many various definitions of project complexity have been provided, but there is no consensus among experts. As a result, it was not found a definition which was universally accepted. So, the researchers reviewed the various definitions in the articles and made a list of them. Then databases were consulted to extract the number of citations to the articles because the number of citations can be a good measure of acceptance of the definition by other researchers.

Table 4 shows these definitions and their frequency. As the table shows, the highest frequency of citations belongs to Williams (960), Baccarini (791), and Tatikonada et al. (727) citations. This means that most of the reviewed articles have named these authors and their articles are considered as references.

Table 4. List of Project Complexity Definitions

	Author(s)	Some of the Project Complexity Definition	Citation
1	Williams (1999)	He refers to definition of Baccarini in his research	960
2	Baccarini (1996)	Consisting of many varied interrelated parts, and complicated, involved, intricate	791
3	Turner et al. (1993)	A definition of a complex project warranting examination would be "*a complex project is one which exhibits a high degree of uncertainty and unpredictability, emanating from both the project itself and its context*"	766
4	Tatikonada et al. (2000)	The nature, quantity and magnitude of organizational subtasks and subtask interactions posed by the project	727
5	Cicmil et al. (2005)	Invokes ambiguity, paradox and the dimensions of time, space, and power of the organizing processes in project settings	296
6	Vidal et al. (2008)	Difficult to understand, foresee and keep under control its overall behaviour, even when given reasonably complete information about the project system	214
7	Remington et al. (2009)	Several characteristics to a degree, or level of severity, that makes it extremely difficult to predict project outcomes, to control or manage project	113
8	Xia and Chan (2011)	Project complexity will influence the project performance and eventually affect the success of a project	82
9	Ellinas et al. (2016)	Complexity is often quoted as an independent variable that challenges the utility of traditional project management tools and techniques.	78
10	DeRosa et al. (2008)	The complexity of a problem situation stems from its openness, interdependence of contributing factors and multi-scalarity	55
	The Collins Dictionary	Defines complexity as "*the state or quality of being intricate or complex*" where complex is defined as "made up of various interconnected parts".	-
11	APM (2008)	The APM describe a complex project as one which will typically involve interaction between several organizations and or different units in the same organization requiring the coordination of the work of several disciplines and involve a wide range of project management methods, tools, and techniques.	-

5.2. Testing the Research Model and Hypotheses

The structural equation model is analyzed using the statistical computer program Amos27. The questionnaire contained 30 variables representing 10 latent variables. To examine the measurement model, the researcher develops a confirmatory factor analysis. Before testing the model and research hypotheses, Cronbach's alpha test showed that the items of each construct have high good validity. As Table 5 shows, it was obtained Cronbach's α values ranging from 0.753 to 0.833, which are adequate according to Porral and Mangin (2016).

Table 5. The Result of Cronbach's Alpha for the Items

Construct	Items	Cronbach's α
Structural Complexity	Organizational Structure	0.794
	Teams and Leadership	0.753
	Interested Parties	0.767
	Goals	0.747
Technological Complexity	Technical Factor	0.757
	Interdependency	0.746
	Project Operations	0.803
Environmental Complexity	Economic Factor	0.742
	Social and Cultural Factor	0.746
	Political Factor	0.744
Project Complexity	Structural Factors	0.767
	Technological Factors	0.832
	Environmental Factors	0.833

Structural equation modelling was used to test the hypothesized relationships, via the maximum likelihood estimator of Amos 27. The findings support the proposed conceptual model. According to Table 4, good fit indices show the fit of a model with the measured data. In general, each of the indicators obtained for the model is not solely due to the suitability or non-suitability of the model, but these indicators should be interpreted together. As can be seen, the main fit indices of the model are within an acceptable range.

Table 6. Fitting the Research Model

Indicator	Acceptable Amount	Calculated Value
χ^2 /(df)	< 5[1]	3.12
Probability Level	< 0.05	0.00
CFI	> 0.90	0.93
NFI	> 0.90	0.90
RFI	0.8 – 0.9	0.84
IFI	> 0.9	0.93
PNFI	> 0.6	0.6
RMSEA	< 0.08	0.07

As the table above shows, all indicators are at the standard level and confirm the model. So, the fit of the proposed model is confirmed. After testing the fit of the model of the research, using the critical ratio and foundation indices, the research hypotheses were tested, and their results are presented in Table 7. In this process, the significance level of 0.05 critical ratio (CR) must be greater than 1.96. Also, a value less than 0.05 for p-value indicates a significant difference calculated for regression weights (factor loads) with a value of zero at the confidence level of 0.95 (Calvo-Porral and Lévy-Mangin, 2020).

Table 7. The Relationships among the Research Constructs

Constructs	Estimate	S.E.	C.R.	P-value	Result
Environmental < --- technological	-0.975	0.185	-5,270	0.00	Supported
Structural < --- technological	-0.238	0.065	-3,659	0.00	Supported
Structural < --- environmental	0.051	0.018	2,858	0.004	Supported
Complexity < --- technological	0.151	0.094	1,602	0.109	Not supported
Complexity < --- environmental	-0.009	0.026	-0.348	0.728	Not supported
Complexity < --- Structural	-1,563	0.350	-4,461	0.00	Supported

The probability of getting a critical ratio as larger as 5,270 in absolute value is 0.001. In other words, the regression weight for technological complexity in the prediction on environmental complexity is significantly different from zero at the 0.001 level (two tailed). In addition, the regression weight estimate, 0.975 has a standard error of 0.185. So, it can be said, when technological complexity goes up by 1, environmental complexity goes down by 0.975. In addition, the probability of getting a critical ratio as larger as 3,659 in absolute value is 0.001. In other words, the regression weight for technological complexity in the prediction on structural complexity is significantly different from zero at the 0.001 level (two tailed). In addition, the regression weight estimate, 0.238 has a standard error of about 0.065.

Thus, it can be said, when technological complexity goes up by 1, structural complexity goes down by 0.238. Also, the probability of getting a critical ratio as larger as 2,858 in absolute value is 0.004. In other words, the regression weight for environmental complexity in the prediction on structural complexity is significantly different from zero at the 0.001 level (two tailed). In addition, the regression weight estimate, 0.051 has a standard error of about 0.018. So, it can be said, when environmental complexity goes up by 1, structural complexity goes up by 0.0.051. Furthermore, the probability of getting a critical ratio as larger as 1,602 in absolute value is 0.0.109. In other words, the regression weight for technological complexity in the prediction on project complexity is not significantly different from zero at the 0.001 level (two tailed).

In addition, the regression weight estimate, 0.0.151 has a standard error of about 0.094. So, it can be said, when technological complexity goes up by 1, project complexity goes up by 0.151. The probability of getting a critical ratio as larger as 0.348 in absolute value is less than 0.728. In other words, the regression weight for environmental complexity in the prediction on project complexity is not significantly different from zero at the

1 The source is (Bollen and Long, 1993).

0.001 level (two tailed). In addition, the regression weight estimate, 0.0.009 has a standard error of about 0.026. So, it can be said, when environmental complexity goes up by 1, project complexity goes down by 0.0.009.

Finally, the probability of getting a critical ratio as larger as 4,461 in absolute value is less than 0.001. In other words, the regression weight for structural complexity in the prediction on project complexity is significantly different from zero at the 0.001 level (two tailed). In addition, the regression weight estimate, 1,563 has a standard error of about 0.350. So, it can be said, when structural complexity goes up by 1, project complexity goes down by 0.350.

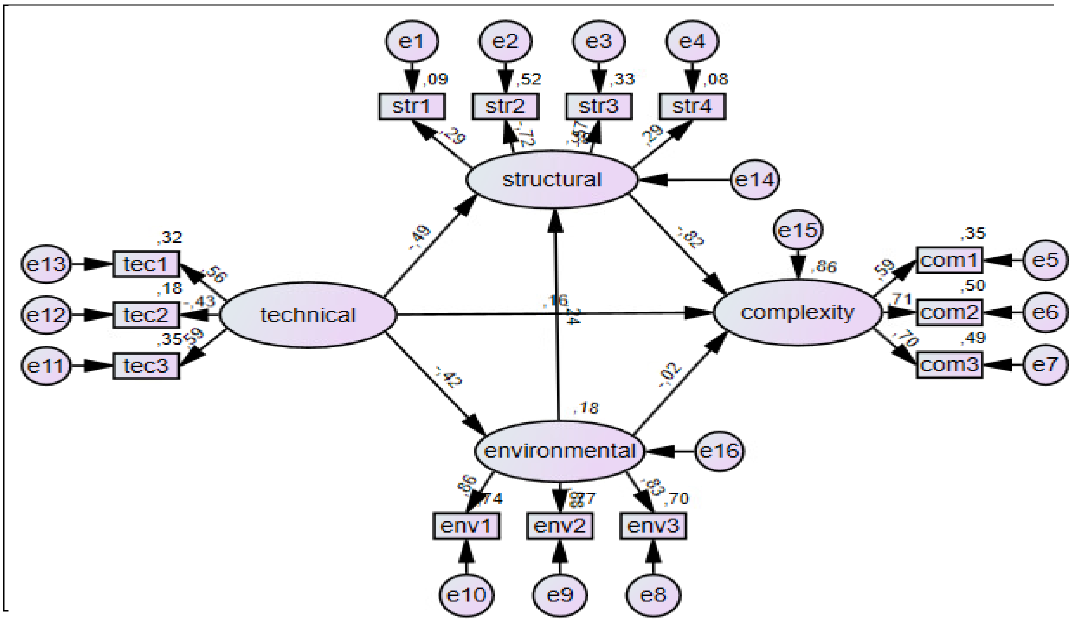
The table below shows the standard weight of each research component. As can be seen, all components have a significance level of less than 0.001. In this way it can be said that all components of research are significantly different from zero at the 0.001 level (two tailed). On the other hand, the estimate's signs of all components are positive. Thus, it can be said that all components have positive impacts of the project complexity so that some like str1, str4, envier 1 to 3 have more impacts than others.

Table 8. Estimate of the Research Components

Component	Estimate	S.E.	C.R.	P-Value
Str1	3,789	0.044	86,420	0.00
Str2	2,562	0.057	44,617	0.00
Str3	1,734	0.048	36,200	0.00
Str4	3,163	0.053	59,416	0.00
Tech1	1,959	0.045	43,918	0.00
Tech2	3,323	0.035	94,737	0.00
Tech3	2,037	0.040	50,425	0.00
Envir1	4,690	0.073	64,492	0.00
Envir2	4,571	0.074	61,412	0.00
Envir3	4,374	0.073	59,758	0.00
Comx1	2,834	0.042	67,425	0.00
Comx2	2,737	0.046	59,473	0.00
Comx3	3,160	0.044	71,097	0.00

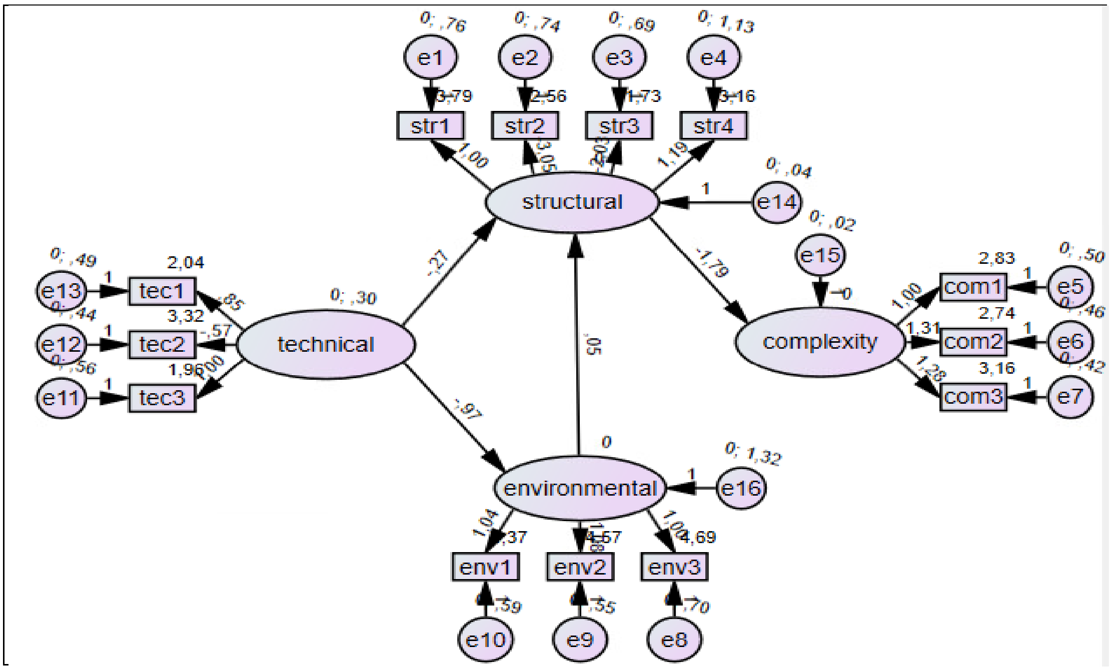
Finally, Figure 3 indicates final structural model of the research. It shows the significant paths.

Figure 3. Estimated Model of the Research



As shown in the figure above, there is a direct relationship between the constructs of the model so that the relationship between technical complexity and structural complexity is 0.49, and the relation between structural complexity and project complexity is 0.82 while technical complexity has a 0.16 direct relationship with project complexity. That means, technical complexity with structural complexity can affect project complexity more than direct relation of these two. Furthermore, technical complexity has a direct and stronger relationship than indirect relationship with project complexity. The weakest direct relationship is between environmental complexity and project complexity with 0.02. The results are also consistent based on P-values in Table 1. As can be seen, the P-values among technical complexity and structural complexity as well as structural complexity and project complexity are 0.00 which both are less than α=0.05. This situation indicates a strong relationship between the variables. However, P-values among technical complexity and project complexity and, also, environmental complexity and project complexity are 0.109, 0.728 respectively, that is more than 0.05. Thus, the relationship among these variables is not enough strong when alpha is 0.05.

Figure 4. Adjusted Model of the Research



Since the relationship between these two factors and project complexity have not been confirmed, it is necessary to adject the model. Therefore, Figure 4 shows the adjusted model.

Table 9. Parameters of Adjusted Model

Indicator	Acceptable Amount	Calculated Value
χ^2 /(df)	<5	3.12
Probability Level	< 0.05	0.00
CFI	> 0.90	0.93
NFI	> 0.90	0.90
RFI	0.8 – 0.9	0.85
IFI	> 0.9	0.93
PNFI	> 0.6	0.61
RMSEA	< 0.08	0.07

The adjusted model shows that the relationships between the variables are strengthened and as shown in table 9, the fit parameters of the model are improved.

5.3. Discussion

The results of the analysis show that researchers have focused on various concepts of project complexity over the past three decades, but a deeper look at these concepts reveals that most of them are sub-factors of organizational, technological, and environmental complexities which have been emphasized in this study. Analysis of statistical data of this study also confirms that all three of these complexities have a significance level of less than 0.05. Therefore, the participants consider them as the main complexities of construction projects.

The number of frequencies of the extracted themes in this study confirms this issue. A review of the literature over the past three decades shows that structural and technological complexities have been emphasized by researchers from the beginning so that technological complexity has been one of the main components of the research of Guidado (1992), Baccarrni (1996), Williams (1999), and Tadikonda (2000). Structural complexity also has been suggested by Baccarrni and Williams. In this study, technological complexity was emphasized by 90% of the participants, but structural complexity is a subset of organizational complexity. If we consider the project as a temporary organization (Sydow, 2018), it has a structure with its own complexities.

As Baccarini (1996) says "*structural complexity involves the scale of the work on the project*" and it refers to the degree to which a task is performed using task specific (as opposed to general purpose) knowledge, teams, interested parties, structures, and goals (Papaioannou and Koutselini, 2007; Robbins et al., 2005). A project is structurally complex when it is large scale, it has many vertical and horizontal differentiations, it is centralized in decision making, and there is a hierarchy system in communication (Robbins, 2005).

It is also structurally centralized and highly formalized (Robbins et al., 2005). Under a structural complexity definition, low structure is more complex than high structure, for example, unfamiliar tasks are more structurally complex than routine tasks (Gill, 2008). A complex organization is made up of different specialized teams and leadership. They as dynamic teams are involving in problem solving, decision making, and motivating in projects. It also has many stakeholders, workstreams or other elements, and many professionals work in (Harrin, 2014).

Stakeholders, including investors, contractors, and suppliers are one of the most important factors in complexity due to their different interests in the projects. Their goals are different from participating in a large project. Sometimes they are rivals. Thus, they add to the complexity and challenge project management. Projects are activities that are based on pre-defined goals. Project goals should be specific, measurable, and achievable. However, due to environmental changes and uncertainty in projects, ambiguity in goals arises. The more ambiguity, the more complexity in projects.Thus, as Bosch-Rekveldt et al. (2011) emphasized in their research, organizational complexity is the most important complexity in the project, and it is how multiple entities of an organization differentiate among themselves. We conclude that organizational complexity refers to the number of resources that are involved in a division, project, or team. If the size of the organizational structure or system is huge that organization is said to be complex.

Technical or technological complexity has the highest frequencies in the research. That is, 90% of the participants emphasized on technological as a main theme of the project complexity. Term of technological complexity first addressed with Baccarini (1996) and Williams (1999), but other researchers have followed them so that it can be seen in almost all complexity research (Remington and Pollack, 2007; San Cristóbal et al., 2018; Vidal and Marle, 2008; Xia and Chan, 2012).

Despite its theoretical relevance and an increasing empirical interest, measuring the complexity of technologies empirically is a complicated issue, and as Tom Broekel (2017) note: "*We do not have any easy way to measure complexity*" (Broekel, 2017). Technological complexity, differentiation would mean the number and diversity of inputs, outputs, tasks, or specialities; interdependency' would be the interdependencies between tasks, teams, technologies, or inputs (Williams, 1999). Therefore, the greater the degree of interdependence between different technologies, and between inputs, outputs, and processes, the higher the complexity of the technology (San Cristóbal et al., 2018). Large construction projects are done based on the latest methods and techniques in the field of building engineering. All activities are performed according to strict standards and instructions. They must be understandable, but a great deal of skill and expertise requires working with these technical instructions. As mentioned earlier, large construction projects require a great deal of financial, human, and raw material resources. Providing each of them is a big challenge for project management that requires various political lobbies and intensive negotiations. Failure to provide any of them at the specified times will delay the project activities and as a result will impose high costs and damages on the project.

Environmental the third complexity that has high frequency in the research. It often emphasized in the projects in the second and third periods of time that mentioned in figure 1. For example, Bosch-Rekveld et al. (2011) added environmental complexity to Baccarini proposal giving rise to their TOE (technological, organizational, and environmental) framework. Environmental complexity refers to the number of elements in the organization's environment and their connections. In a highly complex environment, there are many variables, like economic, social, cultural, and political that can affect the projects complexity (Saylor Academy, 2012). High scores for complexity in this category imply high risks for delay and expensive resolution to lawsuits, public opposition, changes for political considerations, and unforeseen ecological impacts (Algeo, 2014; San Cristóbal et al., 2018). The projects always involve a lot of risk and uncertainty (Floricel et al., 2016; San Cristóbal et al., 2018).

Although feasibility studies in construction projects help to better identify sources of uncertainty as well as provide effective risk management plans in projects (Stefánsdóttir, 2015), uncertainties affect the timing and resource consumption process (Frank and Dearden, 2003) and have negative consequences for projects. One of the unpredictable aspects of projects that add to its complexity is geological conditions. In a difficult natural situation, such as the collapse of a tunnel, or the collapse of a tall building during excavation, a project faces a dead end, and exiting it requires a lot of time and budget. A large project is affected by various factors and the so-called environment. Project management, in addition to internal regulations, must abide by local law or face public resistance. Local people and NGOs have the potential to delay projects. These projects may also destroy or disturb people's property. So, project management must satisfy them. These projects create inter-city or inter-provincial conflicts, and sometimes between countries. The construction of a dam in a region, city or country endangers the position of some people, and this is a cause of conflict. For example, the construction of the Grand Ethiopian Renaissance Dam (GERD) has caused severe conflicts between Ethiopia, Sudan, and Egypt, so that they have gone to war (Brooking, 2020). Based on data analysis and systematic review of research literature, with confirming the conceptual model, other items that have been emphasized in the literature by experts are added to the elements of the model. Thus, the final result is provided in the following framework (Table 10).

Table 10. Components of the Research Final Conceptual Framework

Theme	Main Themes	Catagories	Variables
The factors affecting the assessment of projects complexity in construction field	**Organizational Complexity**	**Structural**	Differentiations
			Size
			Centralization and hierarch
		Goals	Achievable
			Measurable
			Ambiguty
		Interest Parties	Stakeholders
			Contractors
			Suppliers
		Teams and Leadership	Problem solving
			Decision making
			Dynamic
	Technological Complexity	**Methods and Techniques**	Understandable
			Skill and expertise
			Standards
		Resources	Diversity of staff
			Diversity of raw materials
			Amount and diversity of finance
		Interdependency	Technology and process interdependencies
			Components interdependencies
			Specifications
		Project Operations	Safety
			Speed
			Quality
	Environmental Complexity	**Project Site**	Site lay-out
			Unpredictability of work of the site
			Site access
		Geological Conditions	Completely rocky environments
			Earth instability
			Earthquake
		Neighboring Environment	Local Laws and regulations
			Atmosphere
			Property destruction
		Risk and Uncertainty	Absence of knowledge
			Inadequate information
			Probability

Source: The Researcher

In addition, as observed in the previous section, based on the current data from six hypotheses, four hypotheses were confirmed, but two hypotheses were not. Among the confirmed hypotheses, we can mention the relationship between environmental complexity and project complexity, which has been consistent with the complexity literature. In other words, the complexity literature confirms the result because it was expected when the complexity of the project environment, including economic, social, and political factors, increases, the complexity of the project increases too (Ishtiaq and Jahanzaib, 2017).

So, the result is also consistent with the literature, while the other three hypotheses, although confirmed, the results are not consistent with the literature. That is, the relationship between technological complexity and environmental complexity, the relationship between technological complexity and structural complexity, and the relationship between structural complexity and project complexity have been validated based on available data, but the research literature does not support them because based on literature, technological complexity can increase environmental complexity, technological complexity should increase structural complexity, and structural complexity can increase project complexity (Mewes and Broekel, 2020; Robbins, 1990).

Also, the structural complexity is expected to have a positive effect on the project complexity and increase it (San Cristóbal et al., 2018), while the correlation coefficients between them are negative. That is, given the available data, increases in independent variables decrease dependent variables, and this is not according to the literature of complexity. In addition, two hypotheses have not been confirmed. That is, the relationship between technological complexity and project complexity, as well as environmental complexity and project complexity, has not been confirmed, whereas according to the complexity literature, these relationships are expected to be confirmed (San Cristóbal et al., 2018; Vidal and Marle, 2008).

6. CONCLUSION

To achieve the research purposes, based on deductive seasoning, the literature was studied and the opinions of experts from 5 different projects in Iran were collected and analyzed using multiple case study and survey method. Organizational, technological, and environmental complexities were emphasized as the three main themes of the research conceptual framework based on the participants' opinions, which also have strong theoretical foundations in the literature.

Also, among the various concepts extracted from the literature that were emphasized through the survey, for each of the three main complexities, four categories or factors were considered. In the selection of categories, in addition to their frequency, there was also theoretical support in the literature. Finally, each category consists of several variables. As mentioned, these variables can be measured in construction projects and can be evaluated using specific criteria.

The researcher expects the results of this study to help identify the factors of project complexity in the field of construction and be effective in managing the complexity of the project in the field of construction. Its results will be the basis for future research, especially research on the complexity assessment system of construction projects. Also, according to a purely scientific study, this research will develop and improve the definitions of project complexity, structural, technological, and environmental complexity factors, and identify its components to improve the conceptual framework in this field.

Finally, it can be said that based on the data, the statistical results are well explained, and the proposed model is approved, but due to the special conditions that exist in Iran we should be cautious in interpreting and using the results because the country is currently facing a crisis of US sanctions. So, the conditions governing the projects of this country seem a little different from others. In addition, the research population is limited to five cases while it better to expand it to the different cases and projects. To compensate for these limitations, all answers were matched to the literature to ensure their accuracy.

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