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COMPLEXITY FACTORS IN MEGA PROJECTS: A LITERATURE REVIEW

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Abstract

Evaluation of complexity is of considerable importance for project managers in mega projects. Project managers faced with complexities that have not worked so far and are new to their kind. While as for the complexity of project, there is still a lack of complete understanding of the complexity concept among practitioners in the industry as well as in project management body of knowledge. In this regard, the traditional project management principles and practices are not capable of controlling emerging complexities in mega projects. Undoubtedly one of the key factors for success in mega projects is knowledge of project managers about overall complexities and contributing factors on complexities. As the main approach of this paper is overview the factors of complexity in mega projects, a systematic literature review analysis on complexity features in mega projects achieved by examining over one hundred and fifty published research papers during the period of 2012–2019. As a result of this exploration, the research highlighted three (3) dimensions (Environmental, Technological, and Organizational) and over seventy-three factors of complexity in mega projects from the extent literature. The research findings help scholars and practitioners in the project management field developing the perception of complexities in managing mega projects effectively.

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Keywords: Complexity, project management, mega project.



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1. Introduction

Most developing countries are now experiencing mega projects that refers to many industrialized societies in particular industries such as oil and gas, construction, and infrastructure (Figure 1). Bent Flyvbjerg is one of the researchers in the field of mega projects. In 2017 he published a book titled “Managing Mega Projects at Oxford University London”: He defined mega projects as excessively complicated and those that great extend hugely. Mega projects are different from the ordinary projects in the view of investment, cost, process executive and time (Flyvbjerg, 2017). More importantly, mega projects have a direct impact on the community of a country (people and government), economic, level of science and technology as well as the culture (Pitsis, Clegg, Freeder, Sankaran, & Burdon, 2018).

Numerous researchers have claimed that the cost of a mega project that can to be more than multi-million or 1 billion \$ is reasonable to assume the cost issue can be accompanied by complexity (Flyvbjerg, 2014; Hu, Chan, Le, & Jin, 2015). Uncertainty in management has critical influence on project failure, which is an important cause that leads to complexity in mega projects as well. Obviously, mega projects mostly face to the unpredictable challenges associated with cost and time, owing to on the project size and scope (Eriksson, Larsson, & Pesämaa, 2017). Notwithstanding, a contractual context in mega projects is associated with native disputes and a large number of claims in significant magnitude.

Relating complexities in mega projects with organizational behavior, stakeholders and lack of a clear strategic organizational governance policy, in addition to unfamiliarity with local regulations, are mostly caused challenges in team management and execution failures (Mikkelsen, 2018).

Evaluation factors of complexity in design and construction are one of the most important qualifying determinants. These are factors including coordination, innovation, technology, cost, stakeholder, resources, and alike. Executive uncertainty with insufficient integration among the fragmented subprojects creates huge complexity due to the large scale of operations. Coordination within each subproject is not an easy task either.

Most complexities in the view of the importance of mega projects, raise from lack of monitoring and control over sub-projects activities, and lack of knowledge management in relationship with sub-projects and Parent Company. According to the points mentioned above, complexities in mega projects are beyond most controversy surrounds of structural complexity and uncertainty (Bakhshi, Ireland, & Gorod, 2016).

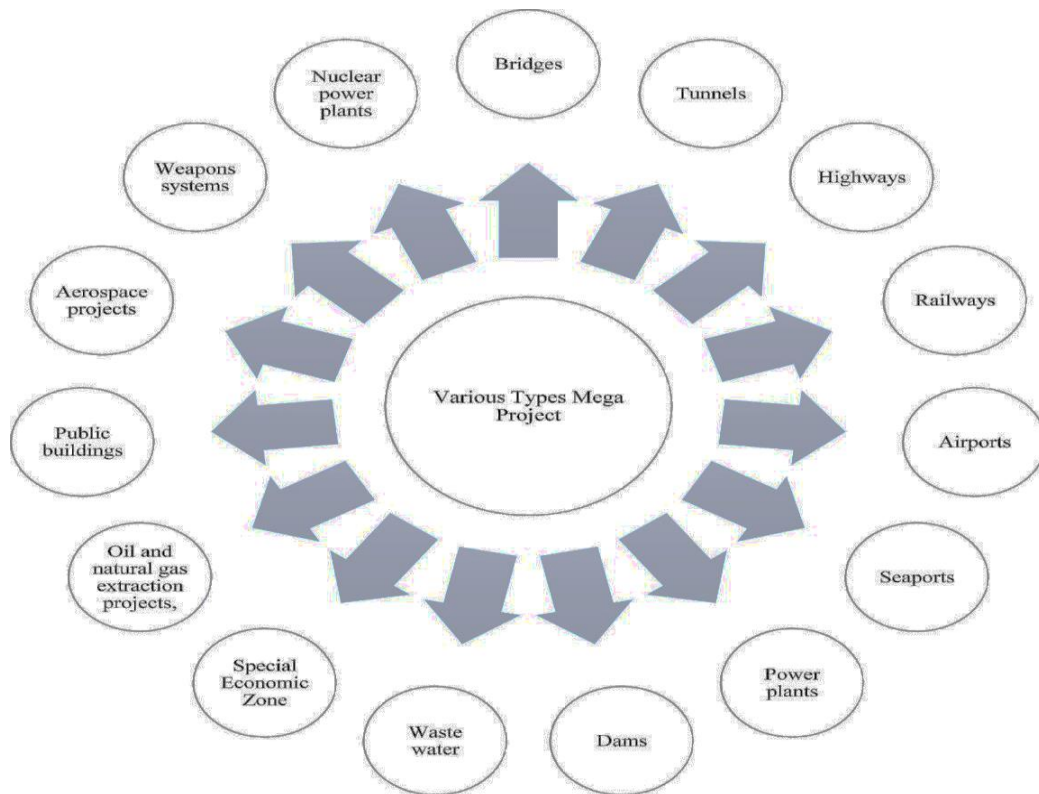


Figure 01. Various types of mega projects considered by publication in the literature review

1.1. Complexities in mega projects

The theory of complexity practically used to define something with diverse parts where those departments relevant to each other in several methods (Bakhshi et al., 2016). Complexity is the reaction of an organization or information of a system that components interact in multiple ways, whereas there is no reasonable instruction to face with conflict the various possible action and reaction (Adeleke et al. 2018). An additional to elaborate on this issue, the given definition of complexity can be expanded to any system. Knew to complexities require to the importance of the subject, such as complexity of the project or complexity of construction. In addition, to better identify project complexity after literature review of various publications, the definitions of the project complexity shown in Figure 02 Obviously that many reasons alternating about complexities in mega projects including, a disordered environment, weak technology, and innumerable possible interactions are certainly identifiable. Mega projects are complex and yet the definition does not consider all possible dimension of complexity because complexity is a reaction and change in the system that be transformed into various forms. Unexpectedly, in ordinary projects faced with specified complexity but in mega projects have unfixed boundaries, which create more elements that are complex, including uncertainty, ambiguity, and interdependency.

Theorists	Year	Definition of Complexity
Mozaffari, Fazli et al	2012	"Complexity is one of the most important issues in the success of any project and there are different studies to identify the important factors that increase the complexity of projects".
Senescu, Aranda-Mena et al	2013	"Complexity is characterized by a complicated or involved Arrangement of many inter-connected elements that it is hard to understand or deal with".
Lessard, Sakhrani et al	2014	"Complexity is an important topic of discussion in major projects research and practice for a variety of reasons. Complexity is an object of management, since understanding a project's complexity is key to properly resourcing it, and finding ways to reduce complexity should improve performance".
Nguyen et al	2015	"Complexity consists of many different Connected parts and can be operationalized in terms of differentiation and dependence".
Dao, Kermanshachi et al	2016	"Project complexity is frequently perceived as a factor imbedded in two major project aspects including project difficulty (how hard the project is to achieve project objectives) and project risks (uncertainties)".
Dao, Kermanshachi et al	2016	"Project complexity has been extensively explored in the literature because of its contribution towards the failure of major projects in terms of cost and time overruns".
Maylor and Turner	2017	"The relationship between complexity and response then is recursive and we propose conceptualizing it as a duality – where the response is simultaneously enabled and constrained by the perceived complexity and vice versa".
Sridarran, Keraminiyage et al	2017	"The term 'complex' as, if the project consists of many interdependent parts, each of which can change in ways that are not totally predictable, and which can then have unpredictable impacts on other elements that are themselves capable of change".
Bjorvatn and Wald	2018	"The adverse effect of complexity overrides the alleviating influence of absorptive capacity on project management success".
Bosch-Rekvelde, Bakker et al	2018	"Increasing complexity of projects is mentioned as one of the reasons for project failure—still".
Hartono	2018	"Uncertainty is seen as an integral part of the later concept of complexity. From the outset, it could be asserted, therefore, that "complexity" perspectives could provide a more comprehensive analytical view than those of risk. Complexity covers risk and other relevant aspects".
Kuhn, Schaefer et al	2018	"Modularization and standardization can create more complexity and complicatedness and must be carefully selected appropriate to the situation".
Makui, Moein Zadeh et al	2018	"Identify the origins of the complexity of the project, it is necessary to identify the causes of the complexity of the project. Six major reasons for the complexity of the project were identified, including: multiplicity, diversity, interdependence, size, novelty, and lack of utility".
Mikkelsen	2018	"There is no commonly accepted definition of project complexity. Given that the field is more than two decades old, it is relevant to research why there are no commonly accepted definitions. Moreover, many different models of project complexity exist based on dimensions similar to the IPMA assessment tool exist, which ought to be further researched".
Turner, Aitken et al	2018	"Complexity is three main types: planning and control, relationship and flexibility responses. The supply chain complexity literature has taken a different tack, broadly dividing responses into complexity reduction and complexity accommodation responses".
Qiu, Chen et al	2019	"Complexity in mega project organizations stems from macro-level and micro-level components, including regulatory, political, and social complexity (macro complexity), and also cultural, relational, and evolutionary complexity (micro complexity)".

Figure 02. Definitions of complexity from the extent literature

1.2. Attributes of complexity

In recent years, researchers have focused on the identification of complexity attributes more than any other issues in the field of mega project complexity (Dao, Kermanshachi, Shane, Anderson, & Hare, 2016). The Forda Institute first used the concept of stakeholders in 1963; they used this concept for all groups and individuals who were involved in the project and affected the project output (Freeman, 1994). Based on the literature on Mega projects, they involve different stakeholders with different approaches and personalities, as well as the level of expectation and benefits in the project. The complexity and instability of these projects require them to have a systematic approach and appropriate project management skills to meet the needs and benefits of the various stakeholders, which is called the complexity of stakeholders (Abdou, Yong, & Othman, 2016), and achieve the highest project output value. Environmental complexities related to the situation in which the project implemented. Issues such as nature, market, political factors, and environmental laws (Lu, Luo, Wang, Le, & Shi, 2015; Zhai, Xin, & Cheng, 2009), this type of complexity can be the bed of the impact of the complexity of stakeholders, those that vary according to their environmental conditions, their interests, and their needs. In addition, some studies have shown that complexity of the environment is one of the most important complications of projects (Bosch-Rekvelde, Jongkind, Mooi, Bakker, & Verbraeck, 2011).

According to previous literature on the complexity of the environment, the primary components of the environment from suppliers, customers, competitors, technology, and socio-cultural factors are the factors that increase the complexity of the environment. Implementation of a project by an organization inducts project forces, organizational structure, and various rules, which results in the complexity of project as a sign of organizational complexity (Lu et al., 2015). Sophisticated megaprojects frequently have specific organizational structures, with varying levels of authority requiring horizontal and vertical alignment (Greiman, 2013). According to recent research, there are many specified definitions of the complexity of project management and its types. However, project analysis and complexity considered in terms of management understanding.

The Federal Bureau of transportation defined Mega projects with more than \$ 1 billion in compared to other projects, but this does not only depend on features, sizes, and locations and the geographic location of the project (Sato & Milton, 2014). Mega projects define broad projects that consist of several teams that quickly, intentionally and deeply in perspective, the need for coordination, capital and government power (Greiman, 2013). In general, Mega-projects have complex financing schemes that include loan, impartiality, grants, stocks, notes and support from non-profit organizations and several supporters from both communal and particular sectors. Mega-projects have a lot of employees over their lives, as well as a joint impact and space constraints on tasks (Lu et al., 2015; Zhai et al., 2009). These projects are faced with multiple and multifaceted tasks in a variety of areas, which will not only include engineering, technology, finance, or organizational management, but will include factors such as environmental protection, social stability and energy storage (Rolstadås & Schiefloe, 2017). These tasks are inseparable from each other and have hidden or obvious relationship. Changing each of the tasks will alter the other tasks. Each of the tasks is in non-linear interaction with another, which increases the complexity of the project (Lu et al., 2015).

For efficacious mega project, success is not only an important and effective operation for a team, but also a success for the national community as well as the state (Dunovic, Mladen, & Skreb, 2014). Mega projects are managed under conditions such as high ambiguity, uncertainty, complexity, budget and time in the form of very complex implementation, paradoxes, uncertainties as well as impacts and uncertainties (Dunovic et al., 2014; van Marrewijk, Clegg, Pitsis, & Veenswijk, 2008). The complexity of a project with a series of uncertainties and ambiguities is one of the inherent features of Mega-project (Dunovic et al., 2014).

2. Problem Statement

There is a need to study complexity as a separate factor influencing mega projects. This includes defining mega project complexity, studying the individual and most important facets of complexity, and identifying the factors of mega project complexity on different aspects of mega projects such as cost, schedule, quality, and project performance. Aspects of complexity known to be constantly changing variables such as project type, project size, project scope, project team experience, interfaces within a project, logistics, market conditions, political and social issues, and permitting and approvals. Better understanding factors of mega project complexity and creating a complexity management strategy will influence how efficiently and economically projects planned, executed, and managed. Project managers need to investigate the complexities that arise in a Mega-project to increase their success in such projects. Each Mega-project has a specific framework for identifying complexity. Scholars believe that with a proactive complexity management plan, a mega project may face less frequent severe complexities.

3. Research Questions

According to the literature review and recent studies on the complexities of mega projects, the research questions have been raised to direct research to the focused purpose.

- What is complexity in projects?
- How will project complexity be characterized?
- How will the definition of mega projects and their complexity be measured?
- Which factors have more influence on the complexity of mega projects?

4. Purpose of the Study

The overall purpose of this research to address research questions is to provide a model for describing complexity based on literature review and then measuring them. The purpose of this process is to determine the complexity of mega projects, identify the complexity factors in mega projects, and then classify them by percentage of impact.

5. Research Methods

The methodology in this research based on literature review of publications that used to study systematic literature to find a theoretical framework of the complexity in mega projects. The systematic

review is a matter of considerable public attempts to collect all experimental evidence that fits pre-specified competency criteria in order (Tranfield et al., 2003). For systematic search, all studies should be identified, using research questions that include the keywords: complexity, mega project, complexity factors, project management. In addition, most valid keywords have been considered in previous studies.

To achieve valid results, both automatic and manual search options used for each bibliographic database. Four stages considered for the research process. The first stage was the selection of related publications on the subject, which included complexity, management, mega projects. In the second step, the publication should be from 2012 to May 2019, focusing on one or more engineering, management, science, and technology sectors of the building, and these publications should have full text available.

In the next stage, the attention based on these publications, which should include the thesis of the books related to the main subject and all articles from the journals in relation to project management, including the International Project Management Journals, International Management Organization, the magazines for managing building projects and the environmental project and executive management. At last, attempts made to categorize all articles in the highest harmony with the complexity of the project. Endnote 9 software used to collect and manage the articles. Total of over One Hundred and Fifty articles have been reviewed on this subject (Figure 3).

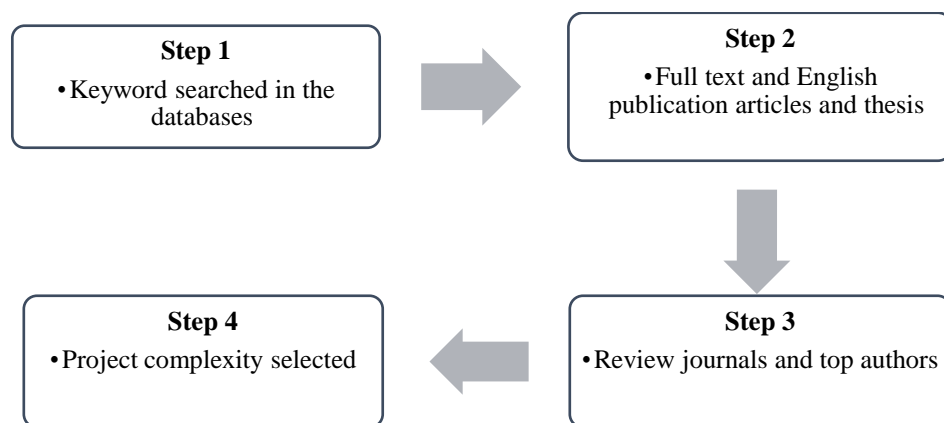


Figure 03. Four stages of the study selection process

6. Findings

In recent years, complexity factors of the project are gathered and used in numerous scientific and practical research. However, there is no such criterion, and as a result, the complexities of mega projects are very vague and varied. In general, these complexities depend on the operational and situational conditions of the mega project. Nevertheless, many factors in different groups affected on complexity in mega project. In other words, complexity factors in mega projects are very numerous (Dao et al., 2016). To help further research and understanding about the complexity of mega projects, it is important that these factors define a specific framework. After analysing and scrutinising literature, the distinction between their views is inevitable. Although many of the important features of considering the complexity of mega projects considered in different perspectives, at the end the dominant elements have been categorized in three groups to classify complexity dimension in mega projects. In our view, the distinction

between each mega project could be analysed by the geographic location and brigade of mega project in terms of operation (Figure 1), the new systems used in mega project and organizational structure in mega project. In recent descriptors, each complexity of mega project comprises of independent sectors and different structures that while are relevant to the same mega project and connected to the other sectors and organizations of mega project. The ranking of complexity factors from the in-depth literature review between 2012-2019 are shown in Figure 4.

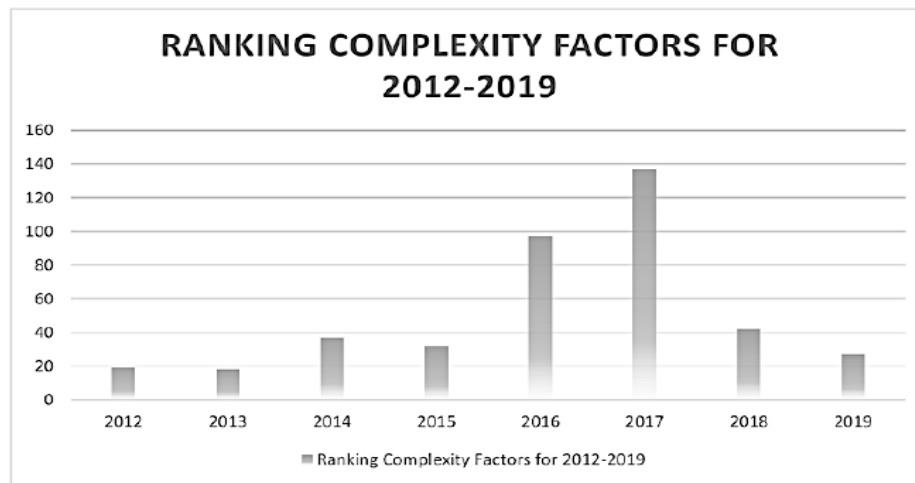


Figure 04. Ranking Complexity Factors based on in depth literature review between 2012-2019

Overall, it is true to say that there are several factors that influence complexities in mega projects (Abdou et al., 2016). To recapitulate, there are diversity factors complexity that depended of specified in mega project and could change the degree of complexity. It is difficult to reach consensus about this issue as a framework of factors complexities in mega projects. Nevertheless, with regard to the previous sections in this research and also used the last outcome during 7 years in terms of the complexity of mega projects, the following tables shows complexity in three dimensions (Environmental, Technological, Organizational). As shown in the tables, the researchers identified more than 75 various complexity factors for mega project in three broad areas (Table 1, 2, 3).

6.1. Environment complexity

Table 1 shows the number of complexity factors in the environmental dimension. The statistics are divided into 21 factors based on referred published papers. Considering the analysis, variety of stakeholder interests, number of stakeholders and relationships between them, changing policy and regulatory, supply chain management are highest referred among 21 items in this dimension. It is clear that the most important cause in environmental complexity external factors. Many external stakeholders participate in mega projects, including but not limited to investors, contractors, governments and suppliers, which will cause social conflicts as a cause of complexity to be occurred.

Table 01. Factors of environmental complexity

Factors	No. referred	Researchers
Variety of stakeholder interests	21	(Bakhshi et al. 2016; Bjorvatn & Wald 2018; Bosch-Rekveltdt, Bakker, & Hertogh, 2018; Callegari, Szklo, & Schaeffer, 2018; Dao et al., 2016; Eriksson et al., 2017; Forozandeh, Ebrahim, & Makui, 2018; Hartono, 2018; He, Luo, Hu, & Chan, 2015; Hu et al., 2015; Abdou et al., 2016; Kuhn, Schaefer, & Otten, 2018; Lessard, Sakhrani, & Miller, 2014; Makui, Zadeh, Bagherpour, & Jabbarzadeh, 2018; Maylor & Turner, 2017; Mikkelsen, 2018; Mirza & Ehsan, 2017; Mok, Shen, & Yang, 2015; Mozaffari, Fazli, & Sedaghat-Seresht, 2012; Nguyen et al., 2015; Qazi, Quigley, Dickson, & Kirytopoulos, 2016; Qiu, Chen, Sheng, & Cheng, 2019; Rolstadås & Schiefloe, 2017; Senescu, Aranda-Mena, & Haymaker, 2013; Shahhossein, Afshar, & Amiri, 2017; Sheffield, Sankaran, & Haslett, 2012; Sridarran, Keraminiyage, & Herszon, 2017; Turner, Aitken, & Bozarth, 2018; van der Maat, 2018; Zhu and Mostafavi 2017; Zhu, Shi, Wu, Sheng, & Wang, 2018)
Number of stakeholders and relationships between them	19	
Understanding stakeholder's project	17	
Environment of changing policy and regulatory	20	
Environment of changing technology	13	
Environment of changing economic	16	
Environment of changing nature	18	
Cultural differences,	17	
Interference with existing site	6	
Remoteness of location	10	
Relationships between different components of the buildings or facilities	8	
Interfaces between different trades and stakeholders	15	
Impact on society	12	
Stakeholders perspectives	16	
Stakeholders interrelations	14	
Relations to mother company	4	
Suppliers	20	
Local community and authorities and customers	13	
Tertiary environment	5	
Agreed market and pricing	11	
Geological/hydrological conditions	7	

6.2. Technological complexity

Table 2 shows 19 items related to technological complexity in mega projects. These factors usually characterize by high technological complexity, such as diversity of technology, innovate technologies of design, dependencies between tasks, breadth of scope and technical risks. The most highest reported complexities in this dimension are related to number and diversity of technology, lack of experience with technology, high variety of tasks and use of very difficult technologies.

Table 02. Factors of technological complexity

Factors	No. referred	Researchers
Ambiguity in the domain the dynamics of work activities	5	(Bakhshi et al., 2016; Bjorvatn & Wald 2018; Bosch-Rekvelde et al., 2018; Callegari et al., 2018; Dao et al. 2016; Eriksson et al. 2017; Forozandeh et al., 2018; Habibi, Barzinpour, & Sadjadi, 2018; Hartono 2018; He et al., 2015; Hu et al., 2015; Invernizzi, Locatelli, Gronqvist, & Brookes, 2019; Abdou et al., 2016; Kuhn et al., 2018; Lehtinen, Peltokorpi, & Artto, 2019; Lessard et al., 2014; Makui et al., 2018; Maylor & Turner, 2017; Mikkelsen, 2018; Mirza & Ehsan, 2017; Mok et al., 2015; Mozaffari et al., 2012; Nguyen et al., 2015; Pitsis et al., 2018; Qazi et al., 2016; Qiu et al., 2019; Rolstadås & Schiefloe 2017; Senescu et al., 2013; Shahhossein et al., 2017; Sheffield et al., 2012; Sridarran et al., 2017; Turner et al., 2018; van der Maat 2018; Zeng et al. 2019; Zhu & Mostafavi, 2017; Zhu et al., 2018)
Number and diversity of technology	23	
Use of very difficult technologies	19	
Dependencies between tasks	17	
Uncertainties in scope	16	
Involvement of different technical disciplines,	8	
Dynamic complexity of a project is affected by internal factors (e.g., human behaviors, material flow, and changes in requirement and scope)	15	
Dynamic complexity of a project is affected by external factors (e.g., social, political and economic issues and weather conditions)	11	
Lack of experience with technology,	22	
High variety of tasks,	20	
Dependencies between tasks,	13	
Technical risks,	11	
Strict quality requirements,	8	
Interrelations between technological processes,	10	
Structure, Production technology,	12	
Number of interdependencies within and without,	14	
Breadth of scope,	18	
Number of specialist disciplines involved,	7	
Variety of technologies employed,	12	

6.3. Organisational complexity

The third dimension is called organizational complexity, which involves aspects such as project staff, project goals, project team size, project budget, planning, contract terms, organizational structure and various teams. Each of the 33 cases that listed in Table 3 is highly influencing the complexity of mega projects. The results of the analysis show that among the items that identified from extent literature, the most pronounce factors are related to size of the project budget, subcontractors, contractors, contract terms and planning.

Table 03. Factors of organisational complexity

Factors	No. Referred	Researchers
Number of specializations involved in the project,	4	(Bjorvatn & Wald 2018; Bosch-Rekvelde et al., 2018; Callegari et al., 2018; Dao et al., 2016; Eriksson et al., 2017; Forozandeh et al., 2018; Habibi et al., 2018; Hartono, 2018; He et al., 2015; Hu et al., 2015; Abdou et al., 2016; Kuhn et al., 2018; Lessard et al., 2014; Li et al., 2018; Makui et al., 2018; Maylor & Turner, 2017; Mirza & Ehsan, 2017; Mok et al., 2015; Mozaffari et al., 2012; Nachbagauer & Schirl-Boeck, 2019; Nguyen et al., 2015; Qazi et
Understanding the project management method,	11	
Number of simultaneous projects,	8	
High number of project goals,	16	
Nonalignment of project goals,	13	
Uncertainty of information / goals,	10	
Financial scale,	18	
Qualifications required for contractors,	20	
Conflicting norms and standards,	14	
Subcontractors,	21	
Transportation,	9	
Competitive Priorities,	6	
Availability of resources,	15	

Work experience of members of the organization,	14	al., 2016; Qiu et al., 2019; Rolstadås & Schiefloe 2017; Senescu et al., 2013; Shahhossein et al., 2017; Sheffield et al., 2012; Shi et al. 2018; Silva, Akchurin, & Bebbington, 2018; Sridarran et al., 2017; Turner & Xue, 2018; Zhu & Mostafavi, 2017)
Common vision of the project team,	3	
The size of the project budget,	22	
Project team size,	19	
Planning,	21	
Contract terms,	23	
Applicable rules and regulations,	7	
Uncertainty in the implementation method,	13	
Uncertain management tools,	5	
Lack of trust in project team,	9	
Interfaces between different disciplines,	5	
Building logistics and accessibility,	14	
Number of financial sources,	12	
Dependency and interdependency,	7	
Economic uncertainty,	16	
Number of different nationalities,	8	
Diversity of staff, Project organization,	10	
Social relations and networks,	4	
Unpredictability Low Pace Fast,	6	
Number of contract/work packages,	13	

7. Conclusion

In sum, with the views and comments stated in this paper, complexity issues in mega projects have been reviewed in order to identify the differences and patterns in this subject. On the whole, this review paper collects information on the variability of mega project complexity and the concept of complexity and its features with the use of literary review and analyse. For better expression, in the context of environmental complexity, the study observed political, economic impact as well as supply chain management as the most stimulators for complexities in mega projects. High ranked parameters that influencing technological complexity could be included the number and diversity of technology, high variety of tasks and lack of experience with technology. The most outstanding factors to the complexity of organization in mega projects are relevant to contractors and contract terms, size of the project budget and planning. The collection of this framework could be contributing to the complexity of mega projects in the structuring of the type of dialogue and decision making by senior project managers and project stakeholders. Moreover, this level of analysis is a broad topic for further research in the future, therefore, further investigation could determine the percentage of the impact of each of the complexity factors in mega projects.

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