Dimensions of Complexity Factors of Industrial Projects and their impact on Constructability Timing Decision

Dr. Ali Ali Shash
Construction Engineering & Management Department, King Fhad University of Petroleum & Minerals
Dhahran, Saudi Arabia.
aashash@kfupm.edu.sa

Saleh Almufadhi
Construction Engineering & Management Department, King Fhad University of Petroleum & Minerals
Dhahran, Saudi Arabia.
almufadhi@gmail.com

***Abstract*— Numerous studies have distinctly addressed the constructability and the project complexity, but there is no study connecting them. This study aims to define industrial project complexity and measure project complexity's impact on constructability implementation and timing decisions. The required data were collected through a questionnaire from stakeholders of complex industrial projects in Saudi Arabia. The stakeholders define project complexity through numerous factors but with different intensities. A medium or a high complexity dictates stakeholders to implement constructability in industrial projects at the preliminary engineering phase and to continue through the detailed engineering and construction phases.**

***Keywords*— Complexity factors; Constructability; Project complexity; Saudi Arabia**

1. INTRODUCTION

Although the project management concept was born in the chemical industry in the 1930s [1], it did not emerge as a practitioners' discipline until the post-WWII developments of technology and infrastructure [2]. Since then, construction projects have been becoming more and more complex [3]. In parallel, the project management discipline continues to grow with remarkable developments in its various constituents by introducing many management tools, techniques, and processes. Project management is primarily about making decisions related to planning, organization, execution, control, and conclusion over the life-cycle of a project [4]. The Project Management Body of Knowledge (PMBOK® Guide) presents many project management techniques and processes in initiating, planning, executing, monitoring and controlling, and closing a project. Unfortunately, despite the noticeable development in the project management discipline, many projects continue to suffer from the inabilities to achieve their objectives, including time, cost, and quality. Reference [5] asserted that the construction industry has a poor history in successful stories of construction projects in terms of cost, time, and quality. It seems that project management, with its modernized and newly developed management tools and techniques, is being implemented. However, unsatisfactory project objective outcomes continue to prevail and characterize the construction industry with a cost overrun, time delays, low quality, etc. Refrences [6] [7] [8] attribute such an industry's poor performance to project complexity. Therefore, project complexity is one of the influencing reasons explaining the project's poor performance. Although it is not uncommon that practitioners and academics in the construction industry designate projects as simple and complex, unfortunately, the designation is not taken into consideration in the implementation of the project management. This negligence causes projects to continue to fail to achieve their objectives and expand the list of unsuccessful projects in the construction industry history. Nowadays, there is an excellent acknowledgment in the literature on the importance of examining project management through the lens of complexity. Many researchers have highlighted the importance of complexity in a project context and its effect on achieving project objectives. The importance of complexity to the project management process is widely acknowledged for several reasons [5]: (i) it influences project planning, coordination, and control; (ii) it hinders the clear identification of goals and objectives of major projects; (iii) it can affect the selection of an appropriate project organization form and experience requirements of management personnel; (iv) it can be used as criteria in the selection of a suitable project management arrangement; and (v) it can affect different project outcomes (time, cost, quality, safety, etc.). Therefore, measuring a project's complexity at an early stage could greatly benefit from managing it successfully.

The project complexity and how it affects project management are of global concern and of great importance to stakeholders of different projects. Many researchers and scholars have studied and argued about the connectivity between project complexity and project management. However, no scholar has discussed the impact of project complexity on a project management tool's decision, i.e., planning, control, communication, coordination, and experience level of the project management team. This study is the first to focus on the impact of industrial projects' complexity on constructability implementation and its timing. The Construction Industry Institute (CII) [9] defines constructability as " The optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives." Several questions were raised in this context: 1) what are the complexity factors in industrial projects? 2) How complexity affect the decision on constructability implementation and timing? These questions could be answered in any construction industry in the world. The authors had the accessibility privilege to the Saudi construction industry to search for answers to the above questions hoping that other industries in other parts of the world will benefit from its outcomes.

It is widely acknowledged that most developed and developing countries' construction industries significantly impact their Gross Domestic Product (GDP) [10]. The Saudi construction industry is considered one of the largest and fastest-growing construction industries in the region [11]. The Saudi construction industry's rapid growth is attributed to two main factors—first, the government strategy to re-build its infrastructure. Second, the significant demand for the private sector [12]. According to reference [13], a total of $575 Billion was spent between 2008 and 2013 in the Saudi construction industry. Reference [14] reported that $610 Billion was spent in the Saudi construction industry between 2015 and 2020. According to Mordor Intelligence, the ongoing construction projects in Saudi Arabia are at a value of $819 billion. Most of the current projects are associated with re-building the Kingdome infrastructure. The current and future projects, including industrial, are considered complex due to many factors (large-scale, massive involvement of international and national organizations, location of projects … etc.). Future projects are characterized as complex. Many researchers have attributed project failures to the weakness of project management of complex projects.

2. OBJECTIVE OF THE STUDY

This study investigates the factors driving industrial projects' complexity and how they impact the constructability implementation and timing decisions. The following goals were set to achieve this aim:

- Determine the factors that owners, designers, and contractors consider to define the complexity of industrial projects; and
- Determine the impact of the project complexity on the constructability implementation and timing decisions.

3. LITERATURE REVIEW

Project management was introduced to the construction industry in the 1950s as a formalized structured approach to manage construction projects properly. However, projects continue to show poor performance in achieving their objectives, e.g., cost, time, quality, and safety. Researchers in construction industries simultaneously analyzed and diagnosed the causes of project failures and designed methodologies, and introduced new managerial tools to eliminate or mitigate the effect of those causes on project performances. Consequently, project management has expanded. Today, it encompasses theories, principles, methodologies, and practices that have improved the project management ability to collect and analyze project requirements and stakeholder information. Despite the significant expansion, projects continually fail at a steady rate.

Constructability was introduced to the construction industry in the 1970s to improve communication between the construction and design teams, which Emmerson and Banwell in the 1960s attributed to the apparent project failures [10]. The USA Construction Industry Institute (CII) [9] defines constructability as " The optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives." CII Australia improved the constructability concept through the introduction of the constructability principles file in 1992. Furthermore, in the early 1990s, the CII of the United States of America and the CII of Australia collaboratively developed the Constructability Principles File tailored to the Australian construction industry. The CII in Australia developed and introduced the constructability implementation guidelines in 1996. Hence, it added a significant improvement to the constructability concepts [15]. Many researchers have acknowledged that the implementation of constructability leads to the realizations of enormous quantitative (for owners: reduced engineering cost, reduced schedule duration, and reduced construction cost in terms of labor, material, and equipment) and qualitative (improved site accessibility, improved safety, reduced rework, increased communication, reduced maintenance cost, increased focus on a common goal, increased construction flexibility; for contractors steady construction; and for designers: better relationships with clients and contractors, fewer lawsuits, good reputation, professional satisfaction, and efficient designs [16][17] [18][19][20]. The majority of the studies recommend implementing constructability intuitively at the early stage of a project development regardless of the size and type. There has been no research to link the constructability implementation decision and project characteristics in general, and the project complexity in particular. This paper attempts to identify the appropriate timing for introducing constructability to complex industrial projects. It is theorized that a project's complexity affects the owner, designer, and contractor's decision on the timing to introduce constructability.

It is acknowledged that the construction industry has been increasing in its complexity since World War II [6], and it will not disappear but rather will continually increase. In other words, complexity is an integral part of current project characteristics and, without a doubt, will continue to be for future projects. Managing projects to achieve their fundamental goals requires identifying certain critical characteristics. Some research in the construction industry pointed out that project complexity is one of those critical characteristics [21]. Even if the project team has all the needed information about the project, project complexity will still exist, making it difficult to keep every part of the project under control [22]. Measuring project complexity is challenging for the project teams to achieve the project objectives [21]. According to Reference [5], the importance of identifying and understanding the complexity of any project to the project management process helps them determine the required planning, coordination, and level of control. Understanding the experience of success and failure while focusing on the project complexity factors will help project managers in managing complex projects [23]. Moreover, understanding the project complexity, from the management point of view, is very essential and significantly important to the project's stakeholders. Identifying the complexity of any project will help the team in many aspects, such as; Clearly understand the main goals and objectives of the project, Determine the planning, coordination, and control requirements, Determine the required resources and procurement arrangement, and Influencing the project's fundamental goals [5]. In the construction industry, complex projects require special tools and systems from a management point of view. In other words, the developed management practices, tools, and systems for conventional projects have been found ineffective to be implemented for complex projects [24]. Many researchers in the construction industry realize that a proper understanding of complexity theory is essential to improve project management practices and, hence, initiated studies to understand and define project complexity. Unfortunately, most, if it is not all researchers, concentrated their efforts to define complexity with great intention to uncover its adverse effect on project management practices in general but not to a specific project management tool such as when to initiate constructability. Reference [5] warns and emphasizes the importance of identifying and understanding a project complexity to the project management processes amid the rapid growth of the project complexity all over the world [22] and that is to designate the required planning, coordination, and the level of control. Consequently, many researchers have been studying complexity intending to define project complexity. Reference [5] defines the project complexity as "Consisting of many varied interrelated parts," and this definition applies to all project dimensions related to the project management process (organization, technology, environment, information, decision making, and systems). Reference [25] also defines project complexity as "The measure of the difficulty of implementing a planned production workflow about any one or number of quantifiable managerial objectives." Reference [22] and other researchers do agree to define project complexity as "project complexity is the property of a project which makes it difficult to understand, foresee and to keep its overall behavior under control, even in the acknowledgment of reasonably complete information about the project system." Reference [21] define project complexity based on project complexity indicators "Project complexity is the degree of interrelatedness between project attributes and interfaces, and their consequential impact on predictability and functionality." Reference [23] developed a definition for project complexity as "An intricate arrangement of the varied interrelated parts in which the elements can change and constantly evolve with an effect on the project objectives." Despite the expended research effort, complexity is still considered one of the most debatable and important topics in the project management field [23]. Even with the existing extensive research and studies on the project complexity topics, there is still a lack of accepted conceptual definition for complexity among researchers [23][26]. There is no standard definition for the project complexity that applies to all the construction project cases [23]. We believe that complexity definition varies from one stakeholder to another, one project development phase to another, and from one type of project to another, i.e., the complexity of an industrial project is different from the complexity of a building project. Hence, we concur with the assertion of reference [21] to define the project complexity and study its attributes and what can influence the project complexity. However, we recommend performing the study from each stakeholder's point of view, at each phase of the project development, and for different projects.

4. RESEARCH METHODOLOGY

This section presents the steps that were followed to achieve the set objective of the study. The first step involved reviewing the published relevant literature to get acquainted with the project's complex theoretical perspective. The second step was to collect the necessary data from owners, designers, and construction contractors involved in developing industrial complex projects through a questionnaire. The literature review guided its development. The questionnaire consists of three sections. The first section contains questions seeking information on the respondents such as education, experience in the construction industry, familiarity with project complexity, and constructability concept and implementation. The second section contains questions seeking information on the organization, such as age, implementation of constructability in complex projects. The third section contains questions seeking information on the characteristics of complex projects and the implementation of constructability. An intensive investigation of the construction market in the Eastern Province of Saudi Arabia revealed that there are only two owners, five designers, and forty contractors involved in developing industrial complex projects. The developed questionnaire was emailed to all the members of the three identified populations. The third step was to analyze the collected data using simple statistical tools such as frequency, mean, and standard deviation. Besides, the Relative Importance Indices (RII) of several designated variables were calculated as follows:

$$RII = \frac{\sum SR}{W \times N} \quad (1)$$

Where SR is the scale of each factor collected from the survey; W is the highest value of the weight, which equals 5; and N is the number of the participants. The RII values range from 0 (not inclusive) to 1, with higher values indicate great importance.

5. RESULTS ANALYSIS

Because the population sizes are small, the structured questionnaire was distributed in the first quarter of 2019 via email to the 2 owners, 5 designers, and 40 contractors. The questionnaire was followed up with emails, telephone calls, and personal visits to invite and encourage constructability experts to participate in the study. Twenty-five experts from contracting organizations, two from owner organizations, and five from designer/consultant organizations completed and returned the questionnaires. Improving the collected data's reliability mandated restoring questionnaires that had at least 80 percent of their contents duly completed, and the data were provided by constructability experienced experts. Two returned questionnaires, mainly from contractors, failed the above restriction and, therefore, were eliminated. Therefore, all owners and designers and 57.5% of the contractors participated in the study, which is considered way above the typical norm of 20-30% response rate in most postal questionnaire surveying of the construction industry [27]. Thus, the 23 participants from the contractors form a reliable, acceptable, and representative sample. The whole members of the owner and the designer/consultant populations participated in the study.

A. Characteristics of the Participants

The participating experts are college-educated with civil, mechanical, electrical, chemical, and industrial engineering degrees, of which about (56%) of them hold Masters or Doctorate of Philosophy degrees. Moreover, the participants are also certified by one or more professional organizations: 57% are Project Management Professional (PMP) certified, 17% are Professional Engineers certified, 17% are Risk Management Professionals (PMI-RMP) certified, 3% are Fundamental of Engineering (FE) certified, 3% are Program Management Professional (PgMP) certified, and the remaining 27% are certified by other organizations. Furthermore, the participants are active members of one or more professional associations: 60% are members in the PMI, 7% are in ASCE, 7% are in ASME, 7% are in SPE, and 33% are in other members in other professional association. The majority (83%) of the participants have more than ten years of experience in the construction industry, and the majority (63%) have participated in the development and construction of more than six (6) construction projects. The participants occupy different positions in their organizations: participants from owner organizations are Senior Project Engineers, the designer/consultant organizations' participants are Project Managers and Constructability Specialists/Facilitators. Furthermore, the participants from contractor organizations are mostly Project Managers and Constructability Specialists/Facilitators. The participants from the owner, designer/consultant, and about 57% of the contractors are well cognizant of the constructability concept and practices, which 53% gained through job training programs, 43% through self-training, and 33% through courses conducted by their organizations. Moreover, the participants have been involved in a different number of constructability practices. The majority of the participants (67%) have participated in more than four constructability practices, and the remaining have participated in at least two.

The results indicate that the participants are employed in well-established organizations that have been in existence for a long time. The owner organizations have been in existence for more than 25 years and build annually more than 40 complex, mostly industrial, projects worth between $50 to less than $500 million, which are awarded either under design-bid-build or design-build delivery systems. The designer/consultant organizations have been in business for varying years, four have been for less than 15 years and one for more than 25 years, and design annually at least four complex projects, mostly industrial, worth between $50-less than $500 million. The majority (75%) of the contractors also have been in business for more than 10 years and construct annually more than two complex, mostly industrial, projects worth between $50 to less than $500 million. The lump-sum and unit price contracts are the dominant mechanisms for the legal binding between owners and contractors. The owners, the designers, and the contractors indicated that they always, sometimes, and often, respectively, address constructability issues in complex projects' bid documents. Tables 1, 2, and 3 present the number, size, and type of complex projects, respectively, that are developed annually.

In summary, it is with confidence that the participants are well informed in complex projects and constructability practices. Therefore, the participants and their organizations are considered a qualified and trustworthy source of information related to complex projects and constructability. Hence, obtaining information from such calibers increases the reliability of the obtained results.

Table 1: Number of annual complex projects

Number of Complex Projects (annually)	**Owner**	**Consultant**	**Constructor**
Less than 2 projects	0	1	3
2 to less than 10 projects	0	2	10
10 to less than 20 projects	0	1	1
20 to less than 40 projects	0	0	5
More than 40 projects	2	1	4
Total	2	5	23

Table 2: Types of complex projects

Type of Complex Projects	(%) executed projects	Organization		
		Owner	Consultant	Constructor
General Buildings (commercial, housing, etc.)	0	0	2	17
	25	2	2	5
	50	0	1	1
	75	0	0	0
	100	0	0	0
Heavy civil work (infrastructure)	0	1	2	17
	25	1	2	5
	50	0	0	1
	75	0	1	0
	100	0	0	0
Industrial (process oriented)	0	0	0	1
	25	0	2	2
	50	1	1	6
	75	1	1	6
	100	0	1	8
Others	0	2	5	13
	25	0	0	8
	50	0	0	1
	75	0	0	0
	100	0	0	1

Table 3: Size of complex projects

Organization's Complex Projects Size	**Approximate Percentage (%)**	**Type of participant**		
		Owner	**Consultant**	**Constructor**
Less than $50MM	0	1	4	13
	25	1	1	5
	50	0	0	2
	75	0	0	1
	100	0	0	2
50 to less than $100MM	0	0	2	9
	25	2	1	10
	50	0	0	0
	75	0	2	1
	100	0	0	3
100 to less than $200MM	0	0	1	15
	25	2	3	7
	50	0	1	1
	75	0	0	0
	100	0	0	0
200 to less than $500MM	0	0	3	14

	25	0	2	5
	50	2	0	0
	75	0	0	1
	100	0	0	2
More than $500MM	0	2	3	16
	25	0	0	0
	50	0	1	1
	75	0	1	0
	100	0	0	5

B. Project complexity factors

The results indicated that owners, designers, and contractors define project complexity through various factors but with different emphasis. Table 4 presents the Relative Importance Indices (RII) and the rank orders of the complexity factors. It is evident and as expected that owners, designers, and contractors define complexity with similar factors but with different emphasis and perspectives confirming the assertion that complexity is in the eyes of the beholders. The owners consider the "The impact of the project delays," "Quality of Suppliers, Subcontractors, and Contractors," and "Permitting and Regulatory Requirements" as absolutely significant factors in evaluating the level of complexity of industrial projects. The contractors in a similar fashion also consider the last two factors as absolutely significant in evaluating industrial projects' complexity. However, the contractors consider the "The impact of the project delays" as very significant in evaluating industrial projects' complexity. The owners and the contractors build many oil and petrochemical projects to capture economic opportunities in a very volatile market. Delays subject owners to massive opportunity loss to capital investments and contractors to reputation damages and additional costs in such projects. Therefore, owners and contractors measure the impact of project delays in their pursuit of determining the level of complexity in industrial projects. The owners and the contractors also evaluate the local suppliers, subcontractors, and contractors' capabilities in constructing industrial projects. It seems that lacking certain capabilities in the local market direct owners and contractors to more painful options. The owners may seek such capabilities from the international market, increasing the project complexity and cost. The contractors may decide not to bid for those projects. References [28] [29] [30] [31] [32] [33] advised owners to check for the availability of resources and capabilities of contractors before awarding contracts and to choose contractors with a good reputation and sufficient experience. Industrial projects mandate the realization of many permits and compliance with many regulatory requirements. The magnitude of permitting and compliance with requirements seemingly increases for projects with new industrial technologies, foreign contractors, foreign suppliers, and extent of project wright of the way, i.e., a refinery project with pipeline component for transporting either feeds from their sources or refined products to customers. The designers rank order the above factors low because they are irrelevant to their design operations.

The designers and the contractors highly consider "The Degree of the Project Interferences with Existing Facilities and/or Systems" as an absolutely significant complex factor in industrial projects. This factor is a challenge to the designers but terrifying to the contractors. As the interface between a new project and existing facilities increases, the more complex the project becomes. There are many possible forms of interfaces. The designers assumed that the work would need very specialized engineers to connect the new design with those in the existing facilities. For the contractors, the challenge is to build the new project without affecting the existing facilities' operations, especially if that is part of the owner's contractual requirements. The owners consider the interface between the new project and the existing facilities as very significant in defining industrial project complexity. This complexity factor may drive owners to select contractors with capabilities and experience in building projects with minimal interruptions to existing facilities' operations. It is believed that flexibility and constant communication are of great importance under any synchronicity form, which will work only when ground rules and thoughtful plans are made from the start. Therefore, a detailed plan with strict rules must be developed to ensure construction work can carry on with minimal interference with regular operations in the existing facilities.

The designers consider "The Degree of the Project Interferences with Other Ongoing Projects" as the highest absolute significant factor contributing to industrial project complexity. The owners and contractors also consider the former factor but as a very significant factor. According to reference [33], the interface between design and production is the most critical project interface and the most difficult to manage. The designers, owners, and contractors always encounter this factor in phased and program construction.

The owners and designers also consider "The Likelihood of Major Scope Changes" as a very significant complex factor for industrial projects. On the contrary, the contractors consider the likelihood of major scope changes as absolutely significant complex factors for industrial projects. It is commonly acknowledged in the construction industry that very few projects are ever completed according to the original plans and budgets. Scope changes are inevitable, and when major changes are expected, the decision-makers usually develop proper change control processes to minimize their impact. The owners, designers, and contractors seem to be aware of this complexity factor and understand that the further into the project development phases, the higher the cost of the scope changes becomes, even if a slight scope change will have a quite large financial impact. Therefore, it is reasonable to say that recognizing the complexity level in a project will aid each stakeholder in the proper construction implementation and the effective strategy for managing scope changes.

The results indicate that while the owners and the designers consider "The Project Technology Complexity and/or Newness to Project Team" as a very significant factor in defining the level of complexity of industrial projects, the contractors consider it as just significant. Reference [35] provides through confirmatory and exploratory factor analyses a shred of strong evidence that the final measures for project technology complexity and project management styles have adequate validity and reliability.

The owners, designers, and contractors also consider "Internal/External Stakeholders' Complexity" as a very significant factor in defining industrial project complexity. It seems that owners, designers, and contractors evaluate their organizations' status in terms of structure, internal management, trust, and cooperation and how their organizations function concerning the relationships and influences existing in their surrounding environments to define projects' complexity.

The designer/consultant is the only party that considers "The Project Impact on the Environment" as a very significant complexity factor in industrial projects. It seems that the owners impose regulations that mandate the preparation of Environmental Impact Assessment (EIA) for all projects and, hence, the project's impact on the environment is not considered as a complex factor for their projects. The designers have to deal with such a factor and find solutions to enumerated environmental impacts to comply with the set standards and regulations.

The designers and contractors also consider "Safety and/or Security Concerns" as very significant complex factors in industrial projects. This factor is not of deep concern to the owners because they probably do not provide equipment and materials to the site but rather transfer this responsibility to contractors. From the designers' point of view, many industrial projects are computerized and accessible to the internets. Hence, many product and process functions become safety-critical and exposed to IT security attacks. This concern adds tremendous complexity to product and process design. Therefore, designers may use different methods for undertaking the major challenges to design for functional safety and IT security, which is essentially based on reducing the design solutions' complexities by integration [36]. The contractors' concerns may arise because industrial project sites constitute valuable and resaleable commodities exposed to theft, vandalism, and damages.

"The degree of the project sensitivity to the conditions of the markets" is not of significant concern to designers and contractors but is for owners. Naturally, owners keep continuous observation of their projects' economic viability, especially for projects sensitive to their products' intended market conditions.

The contractor is the only party that considers "The Construction Site Remoteness" as a very significant complex factor for industrial projects. It seems that contractors account for the availability of housing for their employees and necessary utilities, which are scarce in remote areas.

Table 4: Project complexity factors

Factors	Level of Significance					
	Owner		Designers		Contractor	
	RII	Rank	RII	Rank	RII	Rank
The likelihood of major scope changes	80%	3	80%	4	82%	2
Safety and/or security concerns	70%	4	84%	3	80%	4
The project impact on the environment	50%	6	84%	3	70%	9
The construction site remoteness	60%	5	72%	6	77%	6
The degree of the project interferences with other ongoing projects	80%	3	96%	1	80%	4
The degree of the project interferences with existing facilities and/or systems	80%	3	88%	2	84%	1
The project technology complexity and/or newness to project team	80%	3	84%	3	76%	7
The degree of the project sensitivity to the conditions of the markets	70%	4	60%	7	71%	8
The impact of the project delays	100%	1	72%	6	80%	4
Internal/External stakeholders' complexity	80%	3	84%	3	78%	5
Quality of suppliers, subcontractors, contractors	90%	2	72%	6	82%	2
Permitting and regulatory requirements	90%	2	76%	5	81%	3

C. Constructability Implementation and Timing Decision

The results, as shown in Table 5, indicate that all the three parties decide on the implementation of constructability based on the measured level of project complexity: high (H), medium (M), or low (L). It seems that the three parties measure the level of project complexity by measuring the intensity of the designated complexity factors. The results indicate that the owners, designers, and contractors consider the implementation of constructability in industrial projects as extremely important when project complexity, as measured from each perspective, is considered at least medium. The determination of the complexity of the industrial projects also provides a basis for determining the appropriate timing for the implementation of constructability. The owners, designers, and the majority of the contractors indicated that the best time for constructability implementation, as shown in Table 6, in high and medium complex industrial projects is as early as the preliminary engineering phase and continuing through the detailed engineering construction phases. It interesting to observe that even when complexity is considered low, one of the two owners, and 3 of the designers, and 5 contractors considered the implementation of constructability in an industrial project as very important, extremely important, and very important, respectively. It is maybe that those parties' organizations impose the implementation of constructability on all industrial projects regardless of their complexity level. However, most owners, designers, and contractors asserted that the best time for constructability implementation is at the detailed engineering phase and through the construction phase, when the project complexity level is low.

The majority of the contractors also establish several concepts in their constructability implementation. These concepts are "Constructability implementation plans are an integral part of the Project Execution Plan," "Project schedules are construction - and start-up sensitive," "Design and procurement schedules are construction-sensitive," "Procurement, construction, and start-up efficiency are considered in the development of contract documents," and "Designs promote construction accessibility of personnel, material, and equipment." Observing the concepts mentioned above reveals that they are mostly construction related.

Table 5: Constructability Implementation Decision based on Project Complexity Measurement

Complexity Level	Complexity Importance Level																	
	Owner						Designers						Contractors					
	EI	VI	MI	SI	NI	RII	EI	VI	MI	SI	NI	RII	EI	VI	MI	SI	NI	RII
Low complex construction projects	0	1	0	1	0	60%	3	0	1	1	0	80%	1	4	15	1	2	70%
Medium complex construction projects	1	1	0	0	0	90%	3	1	1	0	0	88%	2	16	4	0	1	87%
High complex construction projects	2	0	0	0	0	100%	5	0	0	0	0	100%	18	2	3	0	0	93%

Where
EI= Extremely Important, VI= Very Important, MI= Moderately Important, SI= Slightly Important, and NI= Not Important

Table 6: Timing for Constructability implementation

Timing for implementing constructability	**Level of Complexity**								
	Owner			**Designer/ Consultant**			**Constructor**		
	H	M	L	H	M	L	H	M	L
Business case development phase	0	0	0	1	0	0	4	1	1
Study Phase	0	0	0	2	0	0	11	4	3
Scoping phase	0	0	0	4	2	0	16	10	9
Preliminary engineering phase	2	2	1	5	4	2	21	18	10
Detailed engineering phase	1	1	2	5	5	4	17	17	15
Construction	1	1	1	3	3	3	11	10	10

Where
H: High, M: Medium, L: Low

6. CONCLUSION

The owners, designers, and contractors define industrial projects' complexity through several factors but with different considerations. The owners define project complexity mostly through the following factors (ordered from the absolutely significant to significant): "The impact of the project delays," "Quality of Suppliers, Subcontractors, and Contractors," "Permitting and Regulatory Requirements," "The Degree of the Project Interferences with Other Ongoing Projects," "The Degree of the Project Interferences with Existing Facilities and/or Systems," "The Likelihood of Major Scope Changes," "The Project Technology Complexity and/or Newness to Project Team," and "Internal/External Stakeholders' Complexity." The designers define project complexity through the following factors (ordered from the absolutely significant to significant): "The Degree of the Project Interferences with Other Ongoing Projects," "The Degree of the Project Interferences with Existing Facilities and/or Systems," "The Project Technology Complexity and/or Newness to Project Team," "Safety and/or Security Concerns," "The Project Impact on the Environment" and "Internal/External Stakeholders' Complexity." The contractors define project complexity through the following factors (ordered from the absolutely significant to significant): "The Degree of the Project Interferences with Existing Facilities and/or Systems," "Quality of Suppliers, Subcontractors, and Contractors," "Permitting and Regulatory Requirements," "The Likelihood of Major Scope Changes," "The impact of the project delays," and "Internal/External Stakeholders' Complexity."

The defined project complexity dictates the owners, the designers, and contractors' decisions on the implementation and timing of constructability. The owners, designers, and most contractors introduce and implement constructability in high and medium complex industrial projects as early as the preliminary engineering phase and continue through the detailed engineering and construction phases.

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