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Complexity in Construction Projects: A Literature Review

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Abstract: Improper understanding of complexity can be a leading factor in the failure of construction projects. This study aims to provide a better understanding of the complexity of construction projects. For this purpose, this study uses the systematic literature review (SLR) approach to review the related literature and propose a definition for complexity and the criteria that affect the degree of complexity in construction. The results of analyzing 49 studies from the literature showed that, generally, complexity is understood in three ways: the meaning of the word "complexity", system and organizational complexity, and project complexity. Within these three types of definitions, it was found that "interdependency" and "multiple parts/parties" are the most frequently used keywords. The results also showed that another look at the current lingual definition of complexity is needed. Regarding the criteria, the results showed that the "number of stakeholders", "scope and project objectives", and "management structure" are the most important criteria to assess construction project complexity. Accordingly, this study provides a set of recommendations and strategies to help manage complexity in construction projects.

Keywords: complexity; project complexity; project management; construction; systematic literature review (SLR); construction industry

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1. Introduction

In project management, complexity is acknowledged as one of the factors most affecting the success of any project as it affects planning and control activities, organization selection, goal and objective identification, and project outcomes [1]. Construction projects are not an exception as many researchers have linked the high degree of complexity with many construction project outcomes including, but not limited to, cost overrun, delays, low quality, poor safety conditions, disputes between partners, inappropriate management of risks, low levels of client satisfaction, and poor communication between stakeholders [2–17]. Accordingly, improper understanding of the complexity and its sources was considered one of the reasons for construction project failure [18,19].

Due to the significant impact of complexity in construction, the literature has many studies that aim to explain what complexity means. Some studies explained complexity using system- or organization-based understanding [20–23]; while others explained complexity based on its lingual and general understanding [24–27], and others linked it with the overall project context [28–30]. In the construction context, a system encompasses interconnected components working toward a common goal, ranging from materials and equipment to processes and workflows. Systems thinking involves understanding these interactions to optimize performance. For instance, a construction project comprises subsystems such as design, procurement, and construction, all influencing the outcome. Thus, the construction project can be understood as a system of systems (SoS) [31–33].

Nevertheless, there is still no agreement on a clear definition of complexity or its sources [1,34,35]. This is because complexity science is still a new topic in general and in construction in particular [18,34]. Another reason for the lack of consensus might be the different focus by researchers as some adopted a definition for the word "complexity" from its general meaning [20,25,27,36,37], while others focused on the analysis of complexity in organizations or systems [21,23,38–42].

Within the lack of consensus on what complexity means, this study aims to build its results based on the existing literature to provide a systematic understanding of complexity and present the different ways to define the complexity and different significant criteria that impact the complexity in construction projects. Accordingly, this study raises the following two research questions:

Question 1: What can be the proposed definition of complexity in construction projects?
Question 2: What criteria impact the complexity level of construction projects?

Defining complexity in construction projects is significant for both academic and practical reasons. Academically, it fills a gap in the literature by providing a comprehensive review and analysis of complexity in construction projects, addressing the lack of consensus on its definition and sources. Moreover, the study goes beyond previous research by not only identifying criteria influencing complexity but also defining them, enhancing understanding for researchers and practitioners alike. Practically, and based on the above discussion, the study's findings can benefit project managers and construction stakeholders in various ways. Firstly, understanding complexity aids in resource allocation, allowing for more effective utilization of manpower, equipment, time, and budget. Secondly, it enables better risk management by accurately assessing potential risks and implementing appropriate mitigation strategies. Additionally, defining complexity informs project planning, scheduling, cost estimation, and quality management, leading to more realistic timelines, budgets, and deliverables. Furthermore, it facilitates effective communication with stakeholders, aligns objectives, and fosters collaboration. Lastly, defining complexity provides a basis for evaluating project performance and measuring success, ultimately contributing to improved project outcomes and avoiding failure in the construction industry.

This paper is organized as follows: firstly, this section presents the objectives and the significance of the study, then the used methodology to achieve the project objectives is presented. Following that, the article reviews the different types of complexity definitions that were found in the literature and presents the criteria that impact project complexity in construction. At the end of the paper, this study provides a general framework that was developed based on the analysis of the literature review results and presents the conclusion and future directions.

2. Research Methodology

The answer to the research questions was investigated using a systematic literature review (SLR) designed to provide a response to the topic posed. The SLR is an approach applied in many fields to answer clear research questions using a systematic protocol based on inclusion and exclusion criteria while reviewing the related literature [43,44]. Unlike the traditional literature review methods, the SLR is more transparent and comprehensive in covering the selected topic and is expected to have less bias [45,46].

The SLR in this study has two main purposes (1) identifying a proposed definition of complexity in construction projects and (2) defining and explaining the criteria that are the source of this complexity. Following the guidelines of the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA), the SLR is structured around three primary phases: identification, screening, and eligibility [47]. As shown in Figure 1, the research started by identifying the used terms of the research, which are "Construction project complexity criteria" and the search sources. The search was on Google Scholar and covered different sources for scientific publications (e.g., Emerald Insight, Wiley Online Library, ScienceDirect, Taylor & Francis, SpringerLink, ASCE Library, and SAGE Journals). Following that, the inclusion and exclusion criteria were defined. This search included journal articles, conference papers, and reviews that were written in English. To avoid any unneeded sources, the sources that were not in the construction sector or did not cover the topic of complexity in this sector were excluded.

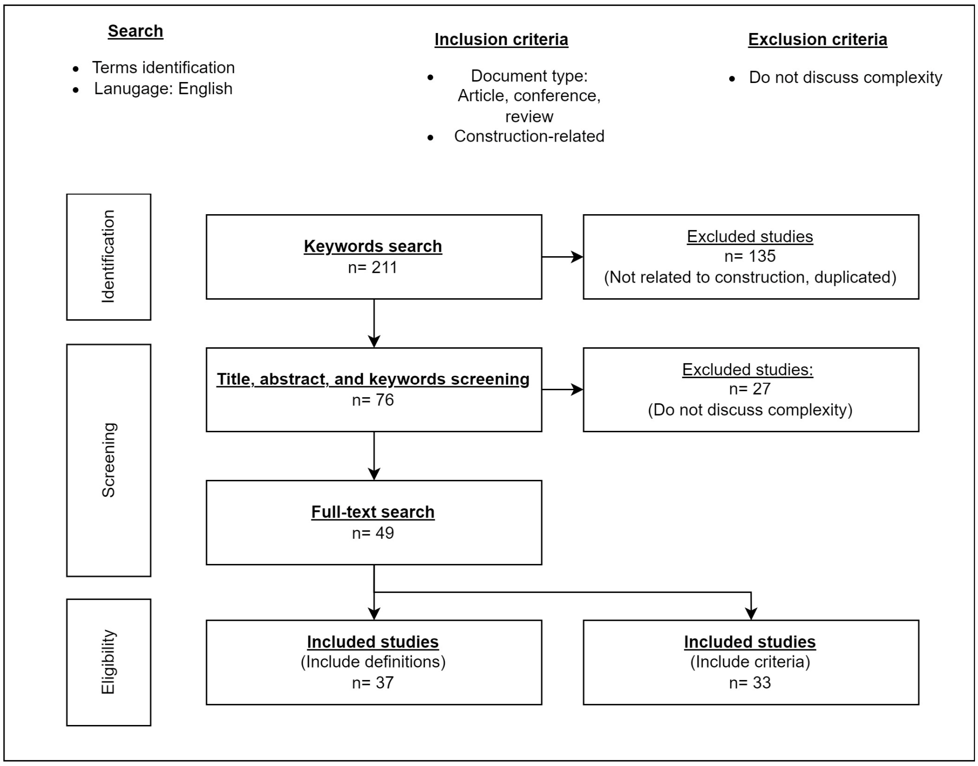

Figure 1. The research methodology was implemented during the study.

The result of the identification phase was 211 studies. Among them, 135 studies were removed due to duplication or lack of focus on construction. The screening phase covered a search of the title, keywords, and abstract and a search of the full text of the sources. During this phase, the sources that are directly related to complexity were selected. Accordingly, 49 studies were eligible to be studied. Among them, 37 included definitions of complexity and 33 identified criteria for complexity in construction projects.

3. Results and Analysis

The current SLR used 49 studies to identify and define the complexity of construction projects and the criteria impacting this complexity. These two axes are presented in this section. Nevertheless, before reviewing the definitions that were found in the search results, it is worth presenting complexity in lingual sources (i.e., global dictionaries) to explore the general understanding of complexity in these sources.

3.1. Complexity in the English Language

According to the *Oxford Learner's Dictionary of Academic English* [48], complexity is "the state of being formed of many parts; the state of being difficult to understand", the complex is "made of many different things or parts that are connected; difficult to understand", and "complicated" is a synonym for "complex". The definition of *Collins English Dictionary* for complexity is "the state of having many different parts connected or related to each other in a complicated way", and complex is "something that has many different parts, and is therefore often difficult to understand". In the *Collins English Dictionary*, complicated, difficult, involved, and mixed are among the synonyms of complex [49]. In the *Cambridge Dictionary* [50], complexity is defined as "the state of having many parts and being difficult to understand or find an answer to", and complex is defined as "involving a lot of different but related parts" and "difficult to understand or find an answer to because of having many different parts".

3.2. Proposed Definitions for Complexity

In regard to the definitions of complexity, the analysis of the search results showed three main groups dealing with explaining the meaning of complexity. These three groups are presented in Figure 2 below. The first group of researchers was interested in highlighting a definition of complexity in its general context. The second group was about the understanding of the system/organizational complexity. The final group proposed the complexity of the projects. The following sections present these definitions and the analysis of the keywords in each of the three groups.

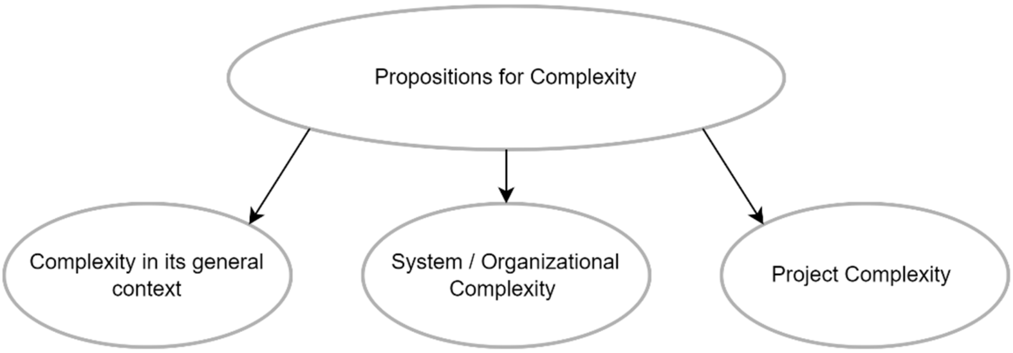

Figure 2. Classification of definition propositions for complexity as found in the literature.

3.2.1. Definitions of "Complexity" in General

The work to explain the meaning of the word "complexity" included many efforts that were varied in the focus; i.e., some studies tried to study the lingual roots and meaning of complexity, while others focused more on the characteristics and components of a complex environment, and others compared between complexity and other types of systems. Table 1 presents a summary of the found definitions and the keywords taken from each of these definitions.

According to Hass [20], complexity is the opposite of simplicity. Edmonds [25] analyzed the term complexity by being interested in the language expression and the behavior of the multiple interrelated components. The study suggested that the lingual definition of the word "complexity" is not enough to predict complex behavior. Jones and Deckro [51] went in the same direction and added a focus on instability. According to their study, complexity is presented as "the variety of tasks", "the degree of interdependencies within these tasks", and "the instability of the tasks' assumptions". In turn, according to Baccarini [39], complexity can be operationalized in terms of differentiation and interdependence and is made up of many different, interacting parts. Tatikonda et al. [24] explained it as the interdependence of product and processing technologies, novelty, and difficulty of objectives. Aram and Noble [52] suggested that complexity is the constant struggle between inactivity and disorder. Bertelsen [53] agreed with that and introduced complexity as the edge of chaos. This idea could also be seen as the behavioral intersection of order and chaos [37,54]. Besides that, Kurtz and Snowden [36] expressed complexity as the patterns many agents form. Other researchers defined complexity as a collection of issues with a wide range of potential relationships, most of which significantly affect decisions [55], or the characteristic of a system that makes it challenging to express its general behavior in a given language [26].

Table 1. Complexity definitions as found in the search results.

Definition	Keywords	References
The variety of tasks, the degree of interdependencies within these tasks, and "the instability of the assumptions upon which the tasks are based"	- Variety of tasks - Interdependency - Instability	[51]
A property of a language expression that makes it difficult to formulate its overall behavior even when we have almost complete figures about its atomic components and their interrelations	- Expression - Behavior - Components and their interrelations	[25,26]
Consisting of many varied interrelated parts and operationalized in terms of differentiation and interdependency	- Interrelated parts - Interdependency - Differentiation	[39,56]
The continually shifting battle zone between inactivity and disorder	- Inactivity - Disorder	[52]
Interdependencies among the product and process technologies and novelty and difficulty of goals	- Interdependencies - Process technology - Product novelty - The difficulty of goals	[24]
The edge of chaos	- Chaos	[53]
How patterns emerge through the interaction of many agents. There are cause-and-effect relationships between the agents, but the number of agents and relationships defy categorization or analytic techniques. Emergent patterns can be perceived but not predicted	- Patterns emerge - Interaction of many agents - Cause-and-effect relationships - Number of agents and connections	[36]
The degree of manifoldness, interrelatedness, and consequential impact of a decision field	- Different functions - Interrelation - Decision impact	[55]
A concurrence of ordered and chaotic behavior is designated as the edge of chaos	- Chaotic - Behavior	[37,54]
The opposite of independent	- Dependent	[20]
The level of difficulty associated with understanding a phenomenon in a given context, mainly because of the complex interaction among its constituents	- Level of difficulty - Understanding a phenomenon - Complex interaction - Constituents	[27]

Given all these definitions, the keywords used for these definitions were analyzed. The results of the analysis of the keywords are shown in Figure 3. The figure shows that "interdependency and interaction or interrelations between items" was the most used keyword while defining complexity, followed by having a large number of components/parts.

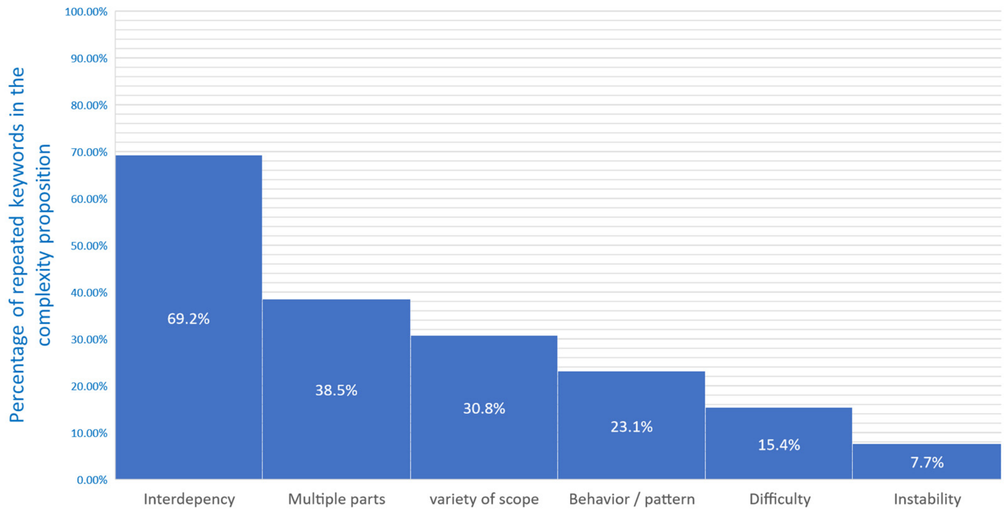

Figure 3. Keywords analysis in complexity definitions.

3.2.2. Definitions for Organization/System Complexity

The second group of proposed definitions focused on organization/system complexity. According to Table 2 below, complex systems are self-organizing systems that evolve through distinct phases [57]. Baccarini [39] asserted that organizational complexity and technological complexity are the two most prevalent types and claimed that the more diverse the parts, the more complex the organization. Uhl-Bien et al. [58] supported this idea and suggested that an organization's complexity is composed of many independent entities; each of them is capable of functioning under unique principles of interaction and relationships. Another point of view proposes an organization's complexity as a system consisting of many interacting parts, each acting within its context following its rules, laws, and forces [23]. In turn, Bertelsen [53] proposed that organizational complexity is more than the sum of the details, and the whole often shows emergent behavior which cannot be predicted by studying the elements. McComb et al. [21] suggested that a system's complexity is composed of many different parts that do not work well together and require much thinking from the person doing the task.

Table 2. Organizational/system complexity definitions as found in the search results.

Definition	Keywords	References
Systems that are self-organizing into stages of greater complexity	- Self-organizing	[57]
Containing differentiated parts so that the greater the differentiation, the more complex the organization. This differentiation has two dimensions: the depth of the hierarchical organizational structure and the number of units and the task structure	- Differentiated parts - Organizational hierarchical structure - Number of units - Task structure	[39]
A combination of numerous interacting parts, each of which behaves in its local framework according to some rules, laws, and forces	- Numerous parts - Interacting - Behavior - Rules, laws, forces	[23]

Table 2. *Cont.*

Definition	Keywords	References
Comprises a large number of items that display a high level of interactivity	- A large number of items - High level of interactivity	[22]
Is more than the sum of its parts, and the whole often exhibits emergent behavior that cannot be predicted by studying the parts	- Emergent behavior - Not predicted - Elements	[53]
Is composed of a large number of independent entities, each capable of functioning by unique principles of interaction and relationships	- Large number - Independent entities - Functioning in accordance - Interaction and relationship	[58]
The multitude of incompatible components that place considerable cognitive demands on the task-doer for execution	- Incompatible components - Cognitive demands	[21]
A system in which many different components interact in multiple ways. It is said to use interwoven components that introduce mutual dependencies and produce more than the sum of their parts. It is the quality of being intricate and compounded	- Many different components - Interact - Multi-way - Intricate and compounded - Interwoven components - Mutual dependencies	[20]
Is consistently characterized by recurring synonymic terms. These terms include (1) numerous, multitude, or large numbers of items, parts, or components; and (2) interaction, interactivity, and interrelation among the aforementioned constituents. The existence of such characteristics in a system that is situated at the midpoint between order and chaos	- Numerous numbers of items - Interaction among the constituents	[38]
Many interconnected parts with emergent properties and may, under certain conditions, behave chaotically	- Interconnected parts - Emergent properties - Behave in a chaotic way	[59]

The used keywords in the definitions of organizational and system complexity were analyzed. The results of the analysis of the keywords are shown in Figure 4. The figure shows that "multiple parts and components" was the most used keyword while defining complexity, followed by having interdependency between these parts.

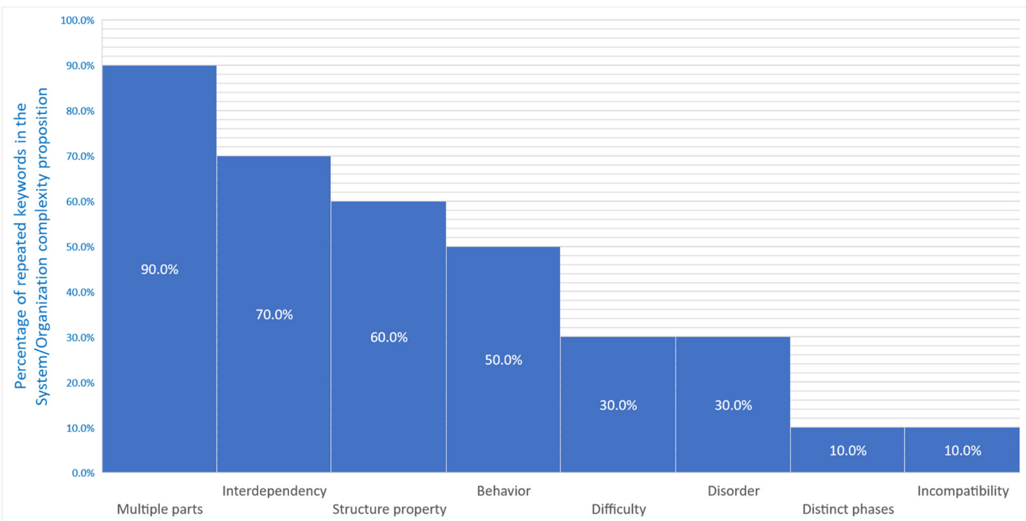

Figure 4. Keywords analysis in organizational/system complexity definitions.

3.2.3. Propositions to Project Complexity

The literature contains many different definitions of project complexity (as shown in Table 3). One definition suggests that a project's complexity involves many separate systems that must be linked together for completion [60]. In turn, according to Luhmannian systems theory, a project's complexity results from the differences in function among its participants, the interdependence of its systems and subsystems, and the effects of any decisions made [61]. For Hass [20], project complexity makes it challenging to manage due to its size, complicated interactions, or uncertainties. Furthermore, Vidal et al. [40] propose that project complexity is the characteristic of a project that makes understanding and controlling its behavior difficult, even with complete project system information. Remington and Pollack [62] asserted that a complex project possesses several characteristics at a particular level that make it very challenging to predict the project's outcomes, management, or control [29]. In addition, project complexity comprises many elements of varied nature that constitute many interactions and flows between these components [30]. Additionally, Remington and Pollack [62] described project complexity as complex systems formed from many elements with emergent behavior. These systems contain interrelationships and feedback between increasing numbers of areas of uncertainty and ambiguity. Moreover, complexity in projects consists of the interrelatedness, differentiation degree, and consequential impact of project elements on the decisions of the project [63]. San Cristóbal et al. [64] affirmed that project complexity can be summarized by the following: differentiation (number of elements in a project) and interdependencies and connectivity (degree of interrelatedness between these elements) which are managed by integration, that is, by coordination, communication, and control [42,65,66]. As shown in Figure 5, the data analysis revealed that the most significant concepts were those of interdependency (80%), multiple parts (66.7%), and system property (60.0%).

Table 3. Project complexity definitions as found in the search results.

Definition	Keywords	References
A project with many interrelated systems that need to be connected. It requires multiple trades to work together on a restricted site with limited access. A project with many complications that make it hard to determine how and when to achieve the desired goals	- Disparate systems - Interrelationships - Multiple trades - Restricted site - Access difficulty - A great deal of complication - Difficulty in executing objectives	[67]
A combination of various interrelated items that can be operated in terms of differentiation and interdependency	- Combination - Interrelated items - Differentiation - Interdependency	[39]
Having a large number of interacting parts, whereas complexity science is the study of these interactions	- A large number of parts - Interaction	[34]
Is closely related to interactions among elements and subtasks of an organization	- Interaction - Elements - Subtasks	[24]
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	- Set of problems - Many parts - Multiple interrelations - Consequence in the decision making - Final result	[28]

Table 3. *Cont.*

Definition	Keywords	References
Challenging to manage because of size, complicated interactions, or uncertainties	- Size - Complicated interactions - Uncertainties	[20]
The characteristic of a project that makes understanding and controlling its behavior difficult even while having complete project system information	- Difficulty in understanding behavior - Having complete information - Unpredictability	[40,68]
Demonstrates several characteristics to a degree or level of severity that makes it extremely difficult to predict project outcomes or control or manage the project	- Number of characteristics - Difficult to predict - Difficult to control or manage	[29]
Made up of many elements of varied nature that constitute it and many interactions and flows between these components	- Many elements - Varied nature - Interactions and flows	[30]
Complex systems formed from many components with emergent behavior that contain interrelationships and feedback between increasing numbers of areas of uncertainty and ambiguity	- Complex systems - Many components - Emergent behavior - Interrelationships and feedback - Increasing numbers of areas - Uncertainty and ambiguity	[62]
The interrelatedness, differentiation degree, and consequential impact of project elements on the decisions of the project	- Interrelatedness - Differentiation degree - Consequential impact - Decision making	[63]
Results from the interaction of different parts with structural, dynamic, and uncertain properties	- Interaction - Different parts - Structural, dynamic, and uncertain properties	[69]
Differentiation, interdependencies, and connectivity are managed by integration, which involves coordination, communication, and control	- Differentiation - Interdependencies and connectivity - Integration - Coordination - Communication and control	[64]
Involves various actions and states of the world parameters as they interact	- Various actions - World parameters	[42]
Is made up of networks of autonomous, independent systems, including people, who have a life of their own as they operate	- Network of systems - Autonomous or interdependent	[65]

Combining the result of the keywords analysis of the three groups of complexity definitions (as shown in Figure 6) leads to the conclusion that complexity results when there are numerous interrelated parts or components whose behavior is difficult to define or predict. Referring to the differentiation of parts or components means having many stakeholders, various tasks, disciplines, teams, or resources. The interdependency between the different parts means that these parts have a relationship and interact with each other in a way that makes it difficult to predict the behavior of the system by studying each part separately.

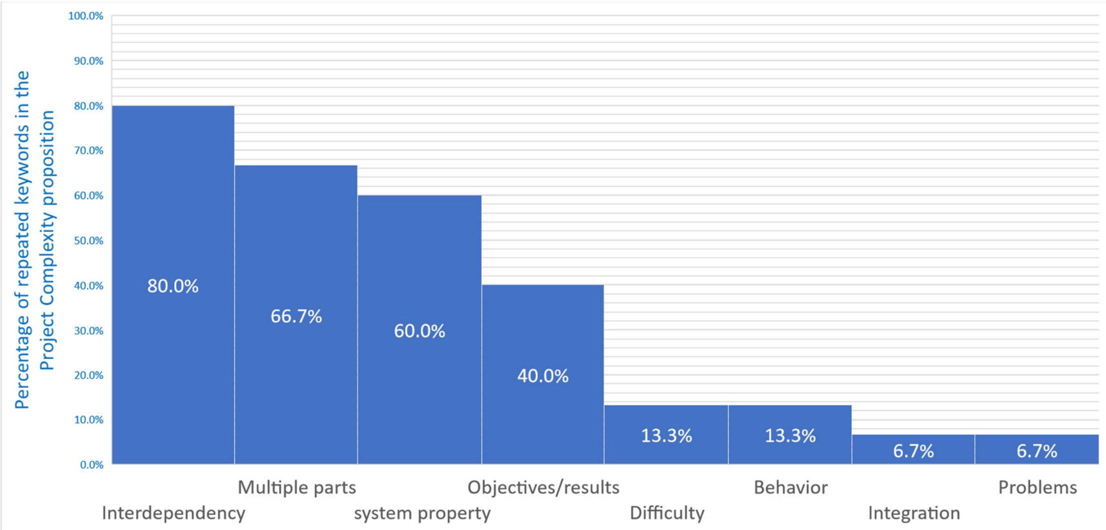

Figure 5. Keywords analysis in project complexity definitions.

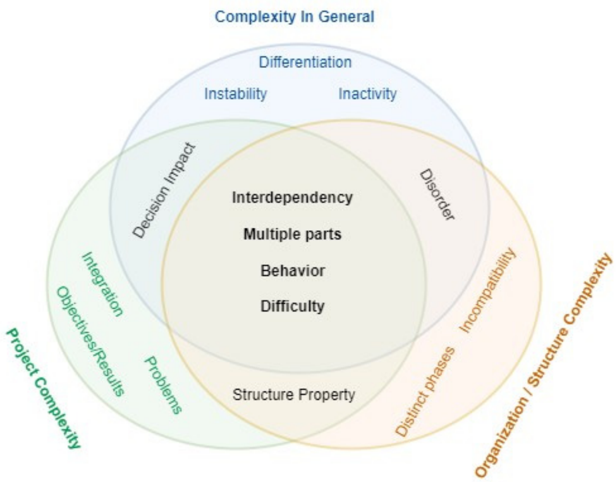

Figure 6. Keywords analysis based on the three groups of definitions.

3.3. Criteria for Complexity in Construction Projects

To answer the second question of the research, which is about the criteria that impact the level of complexity in construction projects, the analysis covered the papers that included different factors, criteria, or drivers that define the levels of complexity in the projects. Accordingly, the analysis resulted in 17 criteria as shown below:

- Number of stakeholders

The first and the most found criterion in the studied sources was the number of stakeholders in the project as it was mentioned in 25 sources. The number of stakeholders affects the level of complexity due to the different visions and goals and creates a conflict of interest [19,20,40,54,64,70–74]. It also impacts the level of site congestion and influences the number of specialists in the project. Additionally, cultural diversity, dispersion in geographical locations of the stakeholders, and their different visions affect the feeling of belonging to the project, shared sources, and the decision-making process [18,40,55,61,64,68,75].

- Scope and project objectives

The second criterion that impacts the complexity of a construction project is the scope. This criterion was found in 24 studied papers. The sources for the complexity of the scope include the number of objectives and activities, interdependencies between these objectives and activities, the number of deliverables, and clarity and understanding of the project scope [19,20,24,25,29,38–41,54,62,68–73,76,77].

- Management Structure

Similar to the project scope, the management structure was found in 24 sources in the studied literature. This is because management structure affects all project management processes and the effectiveness of these processes; including the decision-making process, adoption of specific management practices and leadership styles, change management, knowledge management, risk management, and communication tools [20,24,29,30,34,38–40,51,53,54,68,72,76,78,79].

- Familiarity with the technology

Another criterion for project complexity analyzed by many researchers assumed that the task uncertainty could be generalized from technological novelty and complexity [19,24,40,64]. That is why the company's degree of familiarity with technologies impacts project complexity [38,41]. Other researchers approved and added that the novelty of technology could improve management techniques [39,53,75,78]. Additionally, technology gives rich opportunities for possible applications [20,37,62,72,76]. On the contrary, other researchers considered using complicated technology as a risk [29,30,34,70].

- Communication channels' effectiveness

The complexity of the project increases with poor communication channels [20,37,38,42,75]. That is why, to manage the complexity, improving communication and information sharing is essential [9,20,30,34,40,42,62,64,68,78]. For that, it is necessary to make a clear definition of relationships in terms of communication and reporting [39] and consider the cultural differences between different stakeholders [29,61].

- Laws and regulations

Other criteria for project complexity are laws and regulations, especially unfamiliar regulatory requirements, that necessitate urgent compliance with governmental codes [20,73]. When these regulations are incomplete, unstable, and constantly changing, it is difficult to predict the behavior and the right decisions [19,34,37,38,41,54,56,62,75].

- Availability of resources

The availability of resources, including people, materials, equipment, and expertise, plays a significant role in managing complexity. This is because shortages in resources hinder progress and decrease uniformity in the work [18,19,24,29,30,34,38,40,41,53,62,75,76,80].

- Budget and financial resources

Budget and financial resources identify the possibility of having enough resources and allocating several cost-significant packages that need experts or subcontractors in projects. The number and changes in the timing of funding phases throughout the project are also a source of complexity in the project [38,62,76].

- Project duration

A positive correlation between the level of complexity and project duration was found by some researchers who stated that complexity may increase due to changes over the project duration; these changes can include changes in the regulations and law, technical and financial conditions, sense of pressure during the project, and inability to provide accurate planning for projects [10,56,81]. In turn, Brockmann [61] asserted that project duration increases the understanding of the project.

- Project Location

Project location might affect the level of available infrastructure to support the execution process, impact on populated areas, and site access difficulty, in addition to influencing the execution plans when having different execution locations and differences in cultural background [38,41,74].

- External-environment-related factors

The impact of the external environment can result from different sources, including, for instance, the impact of the weather conditions, market changes, political changes, urgent and unexpected events such as wars and disasters, dependency and interdependency with the environment, and adaptiveness to the surrounding environment [30,38,40,41,62,64].

- Change Orders

Change order refers to any event that causes modifications in the original scope of work [82]. These orders might appear due to many reasons such as design errors, design changes, modifications in specifications, improper technical study during the bidding phase, owner's desire to add or change work, and lack of coordination between different stakeholders [83–85]. The impact of change orders is expected to increase the complexity of construction projects as it evidently can affect a project's duration and cost, decrease productivity, impact the uniformity of the work, and increase pessimistic feelings and disputes and litigations between project stakeholders; especially if these orders appear after the contractual agreement and the construction of major parts of the project [3,20,38,41,85–87].

- Contractual Framework

Contractual management is responsible for providing a high degree of explicitness and elaborateness regarding all work details in the project, including aligning partners' interests, facilitating cooperation, minimizing inefficiencies, adjusting to future internal and external contingencies, handling change orders and claims, allocating resources, engaging partners (e.g., subcontractors), and others [61,88–90]. Therefore, the contractual framework affects complexity in several cases, including, but not limited to, increasing information complexity due to the complexity of communication between partners, increasing organizational complexity due to a large number of conditions and contractual packages, discrepancy and obscurity in documents, and ambiguity and lack of clarification regarding contractual conditions [34,38,91,92].

- Project Planning

During the planning phase, necessary information to carry out the execution work is generated (i.e., project requirements, schedules, resource planning, risks, key participants, etc.) [13]. However, in most cases, planning is based on forecasting, which accepts levels of incorrect inputs. Accordingly, complexity may appear due to these incorrect inputs and affect the certainty of the planning, especially when the horizon of planning is long, some activities are difficult to plan, or when there are dependencies and interdependencies between schedules [30,40,41,62,76].

- Project phase overlapping

Project phase overlapping occurs when there is an overlap between design and construction processes and activities and when there are high levels of interrelations and interdependency between phases and causes an increase in technological complexity due to the diversity of technologies and technological processes in these phases, especially in mega projects [18,38,41,93].

- Turnover and shortage of skilled labor

Construction is characterized as an industry that suffers from a shortage in the skilled workforce due to the tiredness of workers, high turnover rates, and poor safety conditions [94]. As a result, complexity arises from the difficulty of finding skilled laborers who can maintain the progress and uniformity of the work and the reliance on unskilled laborers whose work might be of low quality and have faulty outputs that require rework and whose training is a time-consuming and expensive process [3,38,41,87].

- Effectiveness of risk management

Several risks and their probability significantly contribute to the increase in uncertainty levels [95]. That is why the effectiveness of risk management and the ability to remove constraints were considered to affect organizational and system complexity [18,34,95,96]. Table 4 shows a summary of the results to understand the complexity in construction projects.

Table 4. Summary of the results: Understanding complexity in construction projects.

Understanding complexity	**"Complexity"**	Interdependency	Multiple parts		Objectives/results	Difficulty	Behavior	Instability
	Organization/ system	Interdependency	Multiple parts	System property		Difficulty	Behavior	Chaos/disorder
	Project complexity	Interdependency	Multiple parts	system property	Objectives/results	Difficulty	Behavior	Integration
	Criteria	**Internal criteria:** Number of stakeholders and size of the project Scope and project objectives Management structure Familiarity with technology Communication channels' effectiveness Availability of resources Budget and financial resources Project duration Change orders Contractual framework Project planning Project phase overlapping Turnover and shortages of skilled labor Effectiveness of risk management			**External criteria:** Laws and regulations Project location External-environment-related factors			

4. Discussion

Projects are increasingly becoming more complex and the traditional ways of managing these projects are still unable to respond to the complexity and still producing unsatisfactory results for most measures (e.g., cost, time, quality, environmental impact, etc.) [34,97]. To respond to the increased complexity, it is essential to provide a comprehensive understanding of it and the factors that are affecting its levels.

Despite the importance of understanding complexity in construction, only a few studies have been carried out to meet this goal. Therefore, the current study tries to contribute to the existing work by providing a comprehensive summary of the efforts made in this regard. Accordingly, this study adopted the SLR approach to review the related literature based on the following phases: searching for papers about construction complexity, categorizing the papers based on the two research objectives, which are reviewing the complexity definitions and the factors affecting the degree of complexity in construction projects, and then providing a model to understand complexity in construction projects.

The results of the literature analysis, as shown in Table 4, showed that complexity can be understood based on the literature in three directions: understanding of the word "complexity", complexity in organizations or systems, and complexity in projects. The three types of definitions share four main keywords that might be used to summarize complexity in general, which are interdependency, multiple parts or components, difficulty, and behavior. In other words, the definitions in the literature agree that complexity can result from the interdependencies between different parts or components in a way that makes it difficult to understand or predict the behavior of these components or the whole altogether. According to Bertelsen and Koskela [58], construction can be understood as a complex production of a one-of-a-kind product undertaken mainly at the delivery point by cooperation within a multiskilled ad hoc team. Complexity based on the above points regarding the analyzed definitions is consistent with this understanding. There is emphasis on the need for supporting practices that are based on management as a collaboration between partners where bottom-up management is appreciated and management as learning, where developing competencies to do the right thing at the right time with the support of continuous improvement thinking, is valued [58].

In regard to the lingual or word-based understanding of complexity, the review of the related literature showed that complexity and complicatedness were used interchangeably in some sources [98]. This not completely accurate according to the Cynefin framework [36] that differentiates between the two words as it was stated that, in the decision-making sense, a complicated domain is an order domain in which the relationship between the cause and effect is based on the best practices and, using analysis or expertise, there is a set of right answers and possible prediction for this relationship. Meanwhile, the complex domain is a disordered domain in which the relationship between the cause and effect requires experimental work as there are no preliminary right answers to explain this relationship and the effect. The main source of this disagreement might be the use of the two words "complex" and "complicated" as synonyms for each other in different lingual sources as shown above.

The definitions of complexity are not the only way to understand it; therefore, the search covered the different criteria that may impact the degree of complexity. The analysis of the literature resulted in 17 criteria. The 17 criteria can be classified into four groups; the first group includes project characteristics. Among these characteristics can be found the number of stakeholders, scope and project objectives, project duration, and project location. The second group covers resources and technology and includes familiarity with the technology, availability of resources, budget and financial resources, and turnover and shortage of skilled labor. The third group includes management and process-related factors such as management structure, communication channel effectiveness, laws and regulations, change orders, contractual framework, project planning, project phase overlapping, and effectiveness of risk management. Finally, the fourth group includes external-environment-related factors (e.g., weather conditions, market changes, political changes, and urgent and unexpected events such as wars and disasters).

The number of stakeholders and the size of the project, the scope of the project, and the management structure were among the most repeated criteria in the literature. Additionally, studying the criteria showed that interdependencies in construction projects can be between different components including project partners, project phases, activities, objectives, information systems, trades, and schedules.

Some of the criteria are not internally related to the project structure or components; namely the law and regulations, project locations, and external-environment-related factors. Nevertheless, most of the criteria are directly related to the internal environment of the project. This means that complexity management depends significantly on the internal management of the project. In other ways, facing the increasing complexity might be possible if taking some internal actions and strategic decisions. Examples of these actions and strategies include building effective communication and collaboration channels between the different stakeholders to improve knowledge sharing, understanding stakeholders' interests, trust among partners, and facing risks resulting from the diversity of partners and ambiguity of contractual conditions. Collaboration and high levels of coordination can also be solutions for increasing change orders, unreliable planning, and unclear scope. Additionally, collaborative project management philosophies, such as lean construction and advanced work packaging (AWP), and contractual frameworks, such as integrated project delivery (IPD) or alliance contracting, can eliminate a large set of problems related to knowledge sharing, improper planning, the ambiguity of roles and conditions, lack of understanding of scope, and availability of people and resources. Moreover, training and respect for the role of laborers and experts can be very helpful in facing complexity resulting from turnover and familiarity with technology. Concerning that, the human role and recognition and building human competencies to decrease complexity can be characterized as unappreciated factors in many construction projects around the globe.

This, in turn, can be a source of various difficulties while applying methods and practices that may help improve the collaborative environment in construction [97,99–102].

5. Conclusions

Efficiently managing complexity in construction projects is crucial for project success and to prevent failure, given its significant impact on various project facets, including human relations and resource allocation. Despite its criticality, a universally agreed-upon definition of complexity remains elusive. This study sought to offer a comprehensive understanding of the complexity in construction projects and the factors influencing their magnitude. Employing the SLR approach, the study revealed that existing definitions of complexity lack precision, indicating the need for a broader perspective encompassing organizational, systemic, and project-specific contexts. These perspectives converge on the idea that complexity stems from diverse, interacting components with emergent behaviors, influenced by the interrelatedness and differentiation degree of project elements. Regarding criteria, project complexity can be influenced by various internal and external environmental factors, including the number of stakeholders, project size, scope, and management structure. Consequently, addressing complexity in construction projects necessitates internal initiatives and strategic decisions, such as establishing effective communication channels, fostering collaboration, and embracing technological advancements.

The current study aims to serve as a reference summarizing and supporting previous research on construction project complexity. This summary can serve as a valuable tool for understanding different sources and types of complexity, facilitating effective complexity management and potentially averting project failures. It can also function as a self-assessment tool for managers seeking to gauge the complexity level in their projects. Moreover, future research avenues may involve developing mathematical models to quantify complexity levels, conducting case-specific analyses, and exploring strategies for managing complexity. Additionally, researchers may delve into specific project types, such as mega projects or infrastructure projects, analyze the relationship between complexity levels and project success, or investigate criteria affecting complexity at different project phases or stages.

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