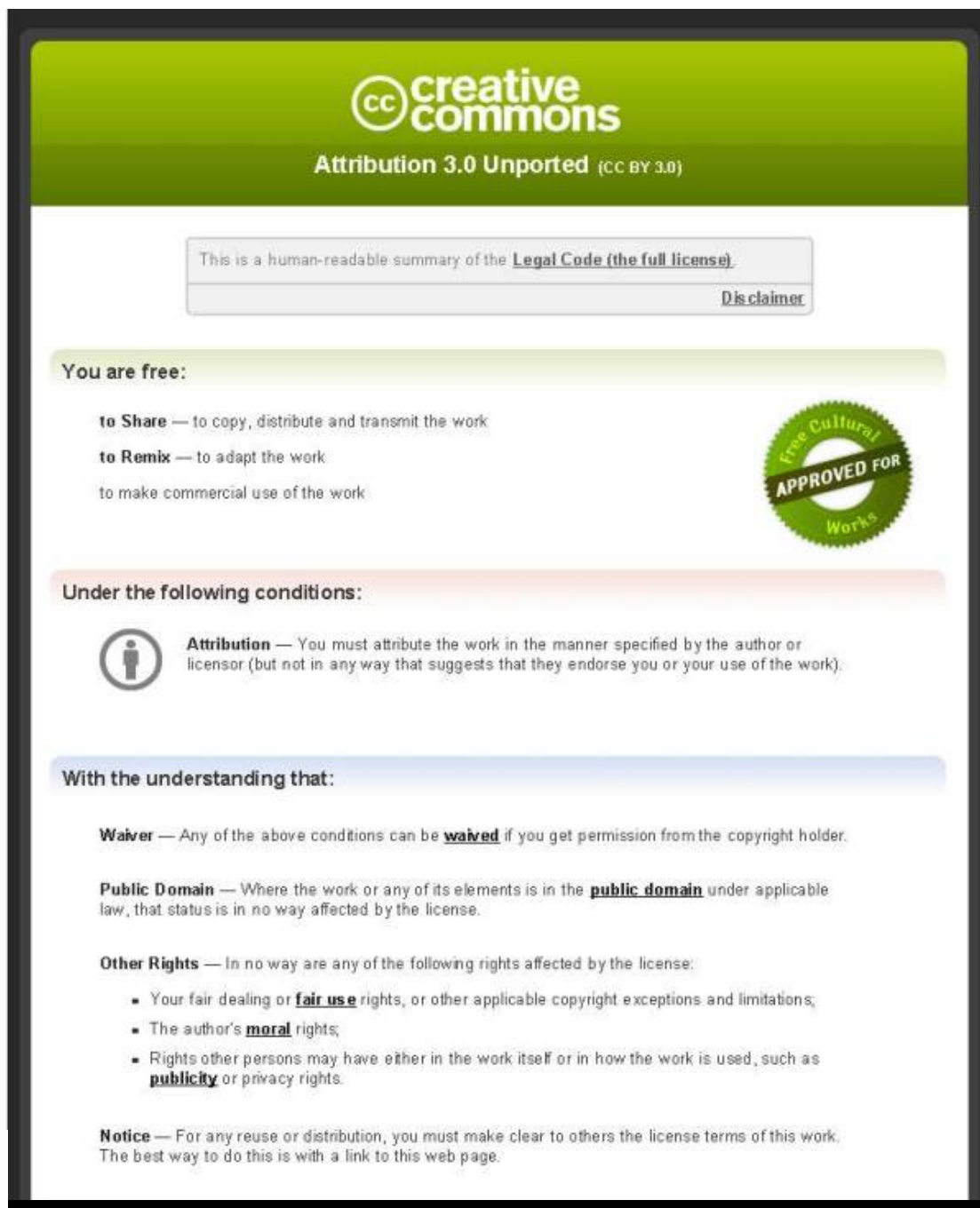


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## Mapping and Simplifying Construction Project Delivery

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### Abstract

The nature of project complexity within construction engineering projects has been the subject of study with growing interest, especially since the Engineering and Physical Sciences Research Council (EPSRC) Networks-Engineering and Physical Sciences Research Council was set-up in 2003. Yet, it could be argued in research terms, that project complexity has been neglected both in terms of conceptualising it and in terms of empirical study. Given the supposed severity of project complexity and the obvious failings of the industry's approach towards project delivery, it is reasonable to assume that such an issue would provide a focus for research to improve practice. The main issues appraised are structural complexity, uncertainty, organisational complexity and technological complexity. As established from the reviewed literature, one of the hindrances to project performance within the construction industry is project complexity, which mainly emerges during the construction and design process.

**Keywords:** Project complexity; Construction; Uncertainty; Organisational complexity; Technological complexity

### Introduction

Numerous studies have attempted to explain project complexity by exploring the various approaches adopted by researchers [1,2]. The theoretical perspective of project complexity; and the “actuality” of complexity within construction projects has been investigated in the literature reviewed, highlighting the lack of consensus on the subject matter [3]. According to Baccarini [4] complexity is one of the critical project characteristics that determine appropriate actions to result in successful project outcomes, with construction projects continuously displaying higher levels of complexity since the mid-1940's. Many other researchers supported Baccarini's [4] view that project success is dependent on the complexity of a project, having a direct effect on the overall project performance [5,6,1]. Evidently, much of the research produced to date by the construction community has failed to consider the application of lean construction as a way to improve project performance by managing project complexity, ensuring the successful delivery of construction projects. Research undertaken by Smith et al. [7] and Bhasin [8] supported this view, noting that the application of lean is what needs to happen for successful project delivery.

In recent years, an increasing amount of research has been undertaken in relation to the subject of project complexity [3]. When evaluating the issue of project complexity, researchers predominately focused on the core platforms of simple project complexity classification and complex systems theory [9]. Azim et al. [3] recognised a lack of agreement among researchers in relation to the definition of complexity. This observation was supported by Xia and Chan [2] who writes that project complexity has not been clearly defined. The only definition of complexity utmost acknowledged by researchers was that of the Oxford English Dictionary, which defined complexity as “consisting of many different and connected parts” and “not easy to understand, complicated or intricate” [3]. As a multi-dimensional concept, defining construction project complexity is incomprehensible. A recent study by Azim et al. [3] obtained several varying definitions of project complexity, with participant responses ranging from; a variety of people in terms of skills and experience, to a multidisciplinary, multi-national, multi-site and a lot of stakeholders. In review of the findings, Azim et al. [3] identified a direct link between project complexity and ‘people, products and

processes’. Azim et al. [3] paper however would have been much more useful, had the authors not failed to consider the implementation of lean tools and techniques in managing people, products and processes of the project environment, which as acknowledged by Winter et al. [10] would subsequently reduce project complexity.

### Theoretical Context of Complexity Theory

Although extensive research has been carried out on project complexity, to date all existing accounts have failed to provide a single, clear definition of project complexity. Xia and Chan [2] pointed out that this is resultant of the fact that the concept of complexity can be utilised in the theoretical context of complexity theory. This section of the literature review therefore briefly outlines the leading theoretical approaches adopted by researchers in defining and characterising project complexity. According to Baccarini (1996) [4] organisational complexity was the amount of operational interdependencies within an organisation (e.g. hierarchical levels and organisational units) and the interface between these operational interdependencies. Technological complexity in contrast; was consigned by Baccarini [4] as the vital requirement for “technologies” and “teams” activities to co-ordinate during project delivery.

Baccarini's [4] classification of ‘organisational’ and ‘technological’ complexity have been identified as the most commonly denoted complexity types, mainly due to the fact that they can “be applied to any project dimension” [3]. Although much of the literature reviewed has widely accepted structural complexity and uncertainty, it has been mainly descriptive in nature [9]. Williams [11] however provided an in-depth analysis of project complexity in terms of “structural complexity”

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and “uncertainty”. Adopting Baccarini’s [4] theory of project complexity, and Turner and Cochrane’s [12] approach of project classification; were project success is either certain or uncertain, Williams [11] attempted to illustrate a distinction between structural complexity and uncertainty [3]. Williams [11] definition of structural complexity, later reaffirmed by Remington and Pollack [12] in their book ‘Tools for Complex Projects’, centred on the fundamental project structure, while suggesting that uncertainty (as defined by Turner and Cochrane [13]) only increases the complexity of the project structure.

Schlindwein and Ison [14] addressed project complexity in terms of descriptive complexity and perceived complexity. According to Schlindwein and Ison [14] complexity was an “intrinsic property of a system”, and where complexity is measureable within a project can be defined as “descriptive complexity”. Perceived complexity on the other hand; was chiefly connected to the observers subjectivity [2,14]. By assessing project complexity in terms of project context; and on the observer’s project experience and perceptions, perceived complexity was the examination of the “actuality” of projects [4,11,9,12]. Up to now the literature reviewed of project complexity has focused predominately on the lack of consensus regarding its definition and the complexity typology. From the theoretical approaches explored, it could be argued that managing project complexity through the utilisation of effective lean construction techniques should be fairly straightforward. However failure of the theoretical approaches to address the relationship between theory and practice challenged this supposition. Complexity theory, in relation to construction project delivery has been strongly challenged in recent years by a number of writers. Xia and Chan [2] pointed out that if construction project complexity was addressed via the behaviour of complex network in complexity theory, then the unpredictable and emergent nature of such a network would potentially inhibit the application of any linear approach. The context of complexity within construction projects raised the question as to how senior construction managers could go about facing the challenges of project complexity, developing an infrastructure of improved construction project delivery. Azim et al. [3] concurred, indicating that the factors contributing to project complexity and their significance on project performance was a more important assessment.

The perception of project complexity was idiosyncratic, influenced by practitioner experience [14] (Schlindwein and Ison). When referring to complexity of construction project delivery, practitioners usually assessed project conditions as being complex, intricate or hard to understand [15,16]. In this review, “project complexity” has therefore been regarded as the features of a construction project that were problematical in its delivery [2]. To comprehend the pragmatic nature of construction projects, practitioner observations of project complexity and the contributing factors were explored [3]. Many researchers argued that it is constructive for project senior management to be aware of complexity factors which affect the overall project, in order to challenge such factors [3,12].

## Factors Contributing to Project Complexity

Geraldi and Adlbrecht [9] recognised project complexity in the practical terms of “complexity of fact”, “complexity of faith” and “complexity of interactions”, based on the theoretical approaches of “structural complexity” and “uncertainty” (as defined by Williams [11]). Table 1 below outlines the actuality of complexity in projects as identified by Geraldi and Adlbrecht [9]. Geraldi and Adlbrecht [9] have concluded that these factors vary over the life of a project. They emphasize that a clear understanding of factor translation helps in selecting appropriate tools and approaches to manage the project.

Group	Factor	Factor Translation
Fact	Size	Size of the project
Fact	Interdependency	Dependency of other departments
Fact	Interdependency	Dependency of other companies
Fact	Number of sources	Quantity of information analyse
Fact	Number of sources	Quantity of sources of information
Fact	Number of sources	Quantity of partner and contact persons
Faith	Maturity	Low level of maturity
Faith	Uniqueness	New technology
Faith	Uniqueness	New partners
Faith	Uniqueness	New processes
Faith	Dynamics	Dynamic
Faith	Dynamics	Various and open options
Interaction		People
Interaction	Transparency	Company politics
Interaction	Multi-reference	Internationality
Interaction	Multi-reference	Multidisciplinary
Interaction		Client

**Table 1:** Actuality of project complexity [9].

Further review of literature identified the following factors contributing to complexity in construction projects:

Firstly, the five factors of complexity as proposed by Chan [17]; buildability of project design, client input, quality management, quality of design coordination, and site condition and access problems. Secondly, the six factors of complexity proposed by Akintoye [18]; complexity of design and construction, expected project organisation, method of construction and techniques, scale and scope of project, site constraints, and the type of structure. And thirdly, the three factors of complexity proposed by Sinhua et al. [19]; workers involved in project activity, materials involved in project activity and tools involved in project activity.

These existing accounts provided valuable practitioner viewpoints of construction project complexity. Most studies in the field however; displayed inconsistencies in project complexity factors, making it difficult to pinpoint the repetitive factors of project complexity that appear in construction project delivery time and time again. Xia and Chan [2] argued that this inconsistency of complexity factors could be related to the underlying structure of the construction industry, which includes various sectors each experiencing different types and levels of project complexity. In their study of construction project complexity, through rigorous analysis and a process of elimination outlined six key factors of project complexity in construction. Table 2 outlines the six complexity factors identified by Xia and Chan [2] and the characteristics of each factor

From their research Xia and Chan [2], noted that building structure and function, construction method, geological condition, neighbouring environment, project size and project schedule affect project complexity (Table 2). It is worth noting that, the complexity of the construction project increases when there is an unrealistic schedule. For instance, project scheduling is intended to match resources of equipment, materials and labor with project work tasks. Whilst, larger size of a construction project does not necessarily lead to higher degree of complexity. Focusing on practitioners ‘lived’ project experience, the key factors contributing to the “actuality” of complexity in constructions projects have been identified. By obtaining a pragmatic view of project complexity, the application of lean construction to construction project delivery has been considered, reducing project complexity and improving construction project performance. A

No	Factor	Complexity Characteristics
1	Building structure and function	<ul style="list-style-type: none"> <li>• Buildability issues</li> <li>• Development of M&amp;E systems</li> <li>• Lack of capability and resources to achieve functions</li> <li>• Specialised functions</li> </ul>
2	Construction method	<ul style="list-style-type: none"> <li>• Qualified technical staff</li> <li>• Specialised staff and equipment for complex buildings</li> <li>• Techniques and processes in the delivery and performance of construction</li> </ul>
3	Geological condition	<ul style="list-style-type: none"> <li>• Ground-work and foundation design</li> <li>• Site investigation</li> <li>• Uncertainty and unpredictability of ground conditions</li> </ul>
4	Neighbouring environment	<ul style="list-style-type: none"> <li>• Damage to neighbouring environment</li> <li>• Site location and access</li> <li>• Specific neighbouring conditions</li> <li>• Weather conditions</li> </ul>
5	Project size and scale	<ul style="list-style-type: none"> <li>• Availability of resources</li> <li>• Complex coordination systems</li> <li>• Management of large construction</li> <li>• Multiple contracts, subcontractors and suppliers</li> </ul>
6	Urgency of project schedule	<ul style="list-style-type: none"> <li>• Design changes</li> <li>• Overlaps of design and interactions</li> <li>• Project scheduling of resources</li> <li>• Resource supply Unrealistic schedule for completion</li> </ul>

**Table 2:** Six complexity factors (Xia and Chan [2]).

number of studies have suggested that traditional project management is based on a hard system model, where planning and control of the project is the central focus [3,10]. A study by Crawford and Pollack [20] however; addressed the relationship between human factors and project complexity, concluding that the main project complexity factor experienced by project managers was the interaction between individuals involved on the project [9]. Some analysts have indicated a divergence from the sole management of the “iron triangle of time, cost and quality”, extending management to the ‘softer’ human factors of communication, teamwork, leadership and conflict management to minimise project complexity [21].

## Conclusion

The literature reviewed identified a lack of consensus regarding the definition, and the theoretical subject matter of construction project complexity. Complex systems are seemingly characterised by unpredictability. Due to the uniqueness of each construction project, evidently high levels of complexity exist within construction. When addressing project complexity from a pragmatic viewpoint, the literary research acknowledged various factors that contribute to construction project complexity. Inconsistency of these complexity factors was a major finding to emerge from the literature reviewed on project complexity. This finding suggests that the underlying structure of the construction industry influenced the type and level of complexity experienced. According to Azim et al. [3] if the complex social processes existing throughout the project hierarchy were managed by the project team, then the nature and source of complexity would be easy to identify and control for the successful accomplishment of project objectives. Conclusive evidence designated that if the cause of complexity in construction project delivery was identified, construction projects would be better managed by the appointed senior construction manager [2].

A large and growing body of literature indicated that project complexity recognition is increasing. With such a revelation; it is no wonder that current project management faces criticism for failing to resolve complexity factors in project practice [3]. Evidently, several studies have revealed that project management must adapt to the dynamic nature of construction projects and their complexities, and

input the corrective techniques to manage and minimise complexity. As established in this review, one of the hindrances to project performance within the construction industry is project complexity, which mainly emerges during the construction and design process. What the construction industry must consider is the integration of lean construction techniques to construction project delivery, and sufficient training to ensure their correct application. For a successful project outcome, clients need to enter the construction process with a clear understanding of their business needs, project requirements and their environmental and social responsibilities and hence the functionality they require from the finished project [22]. Without this clarity at the outset, there are likely to be changes throughout the delivery process resulting in complexity, waste, duplication, poor design, and discontent for everyone.

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