MANAGING COMPLEX PROJECTS IN MULTI-PROJECT ENVIRONMENTS

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Complexity has been identified in both literature and practice as a critical project dimension that needs to be better managed to improve project delivery. Many authors have argued that increasing complexity or the underestimation of complexity accounts for some of the delays and cost overruns experienced on projects. Within the construction industry, the increasing demand for contractors to play integrating roles especially in contractor-led procurement systems (such as Design and Build, and Project Finance Initiative) has added pressure for improved performance. Contractors engaged in such projects usually have other projects going on simultaneously and hence are operating in multi-project environments. However current theory and research reflects mainly the perspective of the client in project, programme and portfolio management, hence applies a single project paradigm to contractors' project business. This paper reviews the nature of complex construction projects in a contractor's multi-project environment and develops a holistic integrated framework to be used for understanding and investigating complex project delivery of projects in this environment. The framework is built on socio-technical system's concept. This broad and enriched way of conceptualising complex projects in multi-project environment, will help organisations not to focus on any one issue at the expense of others. The paper concludes that using this holistic approach holds considerable potential for the managerial improvement of construction contractors.

Keywords: complex projects, contractor, multi-project environment.

INTRODUCTION

Complexity has been identified in literature as a critical project issue needed to be managed to improve delivery. According to a recent study of over 1500 CEO's, "the rapid escalation of complexity" is cited as the biggest challenge confronting organizations (IBM, 2010: p.3). The study further revealed that both the private and public sector enterprises are not equipped to cope effectively with this complexity now or in greater proportions in the future (IBM, 2010). Construction projects have long been described as complex and dynamic. According to Winch (1987: p.970), "construction projects are amongst the most complex of all undertakings". Baccarini (1996: p.201) also emphasises this view by stating that "the construction process may be considered the most complex undertaking in any industry". However, there is no clear, universally accepted definition of complexity. This has resulted in a variety of definitions of the term project complexity. Consequently, both the dictionary and literature definitions will be reviewed to arrive at a working definition for this paper.

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Hagan, G, Bower, D and Smith, N (2011) Managing complex projects in multi-project environments *In:* Egbu, C. and Lou, E.C.W. (Eds.) *Procs 27th Annual ARCOM Conference*, 5-7 September 2011, Bristol, UK, Association of Researchers in Construction Management, 787-796.

In the construction sector, organisations are increasingly under pressure to deliver high levels of performance to the satisfaction of the client and other stakeholders. This means that organisations within the industry need to be able to manage complexity better, but this is not the case. For example, a recent study by The Chartered Institute of Building (CIOB) indicates that most complex construction projects fail to be delivered on time and contractors are predominantly cited to be at fault for the delayed completions (CIOB, 2008).

The construction contractor is at the forefront of managing projects; therefore their influence and impact on delivery to meet the objectives of the project cannot be underestimated. With the increasing demand for contractor-led procurement routes, the situation is even more challenging because of the additional interfaces and issues they present. In spite of this, current theory and research reflect mainly the perspective of the client in project, programme and portfolio management, hence applies a single project paradigm to the contractors' project business (Payne, 1995; Winter *et al.*, 2006). But contractors run multiple projects simultaneously, which makes the environment they operate in a multi-project environment. Therefore it is important that any investigation of how organisations deliver construction projects is done in the context of the environment in which they operate.

The paper is structured in the following way. Firstly the definitions of project complexity are explored from broad views to derive a general consensus and a working definition. Secondly, key factors that influence the delivery of complex construction projects and the contractors' multi-project environment are identified. Thirdly it proposes a concept of maximizing the effectiveness of organisations through socio-technical systems. Based on this concept and the factors identified an integrated framework is developed for understanding and investigating contractors delivering complex construction projects.

PROJECT COMPLEXITY

Concepts of complexity in Project management literature have developed through two streams namely: Complex Projects and Complexity in projects (Geraldi, 2009). Complexity in projects focuses on projects through the lenses of complexity theory whiles complex projects aims at highlighting the dimensions of complexity in projects and is the focus of this paper.

Defining project complexity

Project complexity is increasingly being cited as a contributing factor in project management failure (Flyvbjerg *et al.*, 2003; Gidado, 1996; Remington and Pollack, 2007). According to Xia and Lee (2004), although both researchers and practitioners use the term complexity in writing and practice, no well-defined frameworks exist in literature that can be used to systematically describe their characteristics. The Compact Oxford English Dictionary (2005) defines complexity in two ways as: "consisting of many different and connected parts" and "difficult to understand; complicated". This second meaning is the one that is commonly implied when used in everyday language and also in some literature. The problem with this definition though is that it makes the term subjective because what might be difficult or complicated for one person might not be for another person. Again when this definition is used in the context of project management it creates the impression that complexity is only in the 'eyes of the beholder or observer' and therefore makes it a subjective measure which is not a reliable basis for research analysis (Baccarini, 1996,

Stocks and Male, 1984). Subsequently although this definition is commonly used, it does not provide a firm basis for the formulation of a concise and consistent standard (Baccarini, 1996) and therefore cannot form a working definition for research. Nevertheless, the term has been used in some project management literature to mean large, complicated or difficult (e.g. Gidado, 1996).

In contrast to taking the subjective view of complexity, most definitions in project management literature emphasize the meaning of complexity in terms of structural complexity (interdependence) and uncertainty (Geraldi and Adlbrecht, 2007; Williams, 1999). Although there is a strong body of thought that views these as two separate concepts (Baccarini, 1996; Laufer *et al.*, 1996), there is a general agreement that both contribute to complexity.

Baccarini (1996) defined project complexity as "consisting of many varied interrelated parts' and can be operationalized in terms of differentiation and interdependency". In this definition, the complexity is seen by the interdependencies in the process (task interdependencies, methods), resources (factors of production) and relations (goals, outcomes, expectations) of the construction production. One can therefore deduce that, the more elements and higher degree of interdependence, the higher the complexity.

Tatikonda and Rosenthal (2000) considered project complexity as the nature, quantity, and magnitude of organizational subtasks and subtask interactions required by a project and stated the key determinants of complexity as: the degree of interdependence, newness of project objectives as those defining project complexity. By this definition, complexity is considered as a composite unit embracing the characteristics similar to Baccarini (1996) and Williams (1999).

Other definitions of complexity are based on dynamic and structural complexity. Xia and Lee (2004) defined complexity in terms of the dynamic (or uncertain nature resulting from potential changes that may occur from the environment of the organisation and/or within the project) and structural (organisational and technological) aspects that affect project delivery. Ribbers and Schoo (2002) also defined complexity as variability (similar to dynamic), variety and integration (similar to structural complexity) to capture the environmental characteristics of Enterprise Resource Planning (ERP) implementations.

Thus from the review, project complexity can be attributed to: 1) interdependencies created, for example, as a result of large number of functions and activities ranging from: changes to procurement methods; multiplicity of stakeholders; environmental issues; and different levels of relationships between suppliers (structural complexity); and 2) uncertainty in goals and methods and also of the performance of others (as well as the potential changes that may occur due to the dynamic external and internal environments), in the project delivery process. To be able to capture all or most of the elements that significantly contribute to project complexity, this paper defines project complexity in an over-arching sense to include any single or multiple components of the project system that combines to affect the effective and efficient delivery of the project.

Characteristics of Complex Construction Projects

In this section, complexity is discussed in terms of the characteristics that are unique to the configuration of construction projects (interdependence and uncertainty). It has been argued that the traditional project management approach, which views the

construction process as an ordered, linear phenomenon that can be organised, planned and managed top down, does not accurately reflecting the actuality of the process (Remington and Pollack, 2007; Williams, 2002; Winter *et al.*, 2006). On the contrary, a critical look shows that the interdependencies and uncertainty in the construction project delivery process make planning, organising and execution less predictable. According to Dörner (1997), projects are built systems that consist of elements and connections. Construction is also considered a 'team' industry, where representatives of the client, consultants, and constructors come together to form a temporary organization that interdependently deliver a project. Thus a construction project can be considered as the formation of a temporary organization made up of organizations coming together (as a team) to interdependently deliver built systems that consist of elements and connections. The delivery process therefore becomes the vehicle through which benefits are achieved and relationships mediated, by many variables (such as organisational boundaries) that create the interdependencies and uncertainty. The interdependence is a characteristic of the way tasks are planned, coordinated and executed and/or outcomes are shared in relation to other features of the construction project.

According to Baccarini (1996), interdependence of the construction delivery process can be highlighted in terms of the following:

- Degree of operational interdependencies and interactions between project organizational elements
- The degree of interdependencies between tasks, teams, different technologies and inputs

Gidado (1996) attributes the factors due to interdependence as:

- Number of technologies involved in a task and their interdependencies
- Rigidity of sequence between the various main operations
- Overlap of stages or elements of construction.

Other factors identified include: design and phasing (Bertelsen, 2004); number of participating actors and their interdependencies (Cicmil and Marshall, 2005); and number of sources/elements and the relationships between them (Geraldi and Adlbrecht, 2007).

Uncertainty, as the second dimension underpinning complexity originates from the tasks, employed resources and/or external environment. Gidado (1996) identifies four factors as causing uncertainty in the construction delivery process, namely:

- Incomplete specification to enable execution to be carried out
- Lack of familiarity by management of the operating environment and resources (inputs)
- Uniqueness of projects resulting in lack of uniformity of materials, teams, and work
- Unpredictability of environment.

Turner and Cochrane (1993) argue that the uncertainty of the methods to carry out the project and the uncertainty of goals (or how well the goals or scope of the project are defined) add to complexity of the project. Cicmil and Marshall (2005) point to the unpredictability of project performance, processes of social interaction and ambiguity and equivocal performance criteria among project participators as uncertainty factors that cause complexity. Geraldi and Adlbrecht (2007) also identified the level of project maturity (how well defined); dynamics of project (frequency and impact of

changes); variability (culture, norms or standards); and uniqueness as factors of uncertainty associated with project complexity.

Thus generally, the characteristics of complex construction projects can be categorised into those of interdependence and uncertainty. These include: number of organizational and operational interdependencies, number of tasks, teams, elements, technologies, inputs and their interdependencies, overlap of stages or phasing, employed resources, specifications, operating environment, unpredictable environment, type or uniqueness of project, goals, methods and scope definitions, and variations.

Multi-Project Environment of the contractor

Construction contractor organizations are project-driven, that is, their primary business is projects. Such organizations usually do not have only a single project at a time but run multiple projects simultaneously and therefore operate in a multi-project environment. The projects may or may not be interrelated contractually but may share some common resources from the organization.

Contractually, the main contractor has the obligation to execute and complete the works for which tender has been submitted, within the terms specified in the contract. The reason for engaging the services of a main contractor may be many, but irrespective of that, the role they play is determined by the type of contract entered into, and the procurement option chosen by the client (Murdoch and Hughes, 2000, Twort and Rees, 2003). In the conventional paramount role, the main contractor is responsible for constructing the works as set out in the contract documentation. Normally this role excludes responsibility for design (except for temporary works) and specifications of the permanent works, but includes managing subcontractors and specialists undertaking contracting activities as well as materials, workmanship and equipment required to carry out the works. However, in its contemporary role in contractor-led procurement systems (such as design and build, turnkey, Private Finance Initiatives' (PFI) etc), the main contractor may have the total responsibility of design and construction, operation and maintenance, and funding. The issues and features presented by this role are diverse, ranging from: the relationship of the project team to the client organisation and the client's influence upon critical decisions; the degree of interdependency of tasks and people generated by the project organisational structure; the degree of differentiation present within the operating system; and the level of integration provided by the managing system in the organisation.

However in a multi-project environment, the main contractor would be involved in dealing with the issues raised with regard to not only just one project at a time but in concert with others being simultaneously delivered. Although the other projects may be independent contractually, they may still share important inputs such as people or finance. For example, scheduling of resources cannot be performed independently as if only one project exists, nor can productivity methods only focus narrowly on individual activities without consideration for others. Equally important are the processes and controls organisations use to manage projects the (Abdullah and Vickridge, 2000).

The above review provides a broad premise and opportunity for abstracting and developing an integrated framework for investigating and understanding complex construction projects in a contractor's multi-project environment. To do so would require a holistic approach that is underlined by a coherent theory. The socio-technical system approach provides such basis on which an integrated framework is developed.

The philosophical context

Socio-technical systems theory proposes that the effectiveness of an organization is related to the joint maximization of its social and technical factors (Cherns, 1987, Clegg, 2000, Katz and Kahn, 1978). On the basis of this approach, an organisation can be viewed as a system comprising various interrelated, co-dependent sub-system in a state of dynamic interplay (Clegg and Shepherd, 2007). It becomes necessary therefore, to view the organisation as a single, interrelated system whose sub-systems must be considered jointly for maximum performance. Thus to the extent that organisations are effective and efficient in delivering complex projects, there is the justification for viewing all that is involved in the organisation as interdependent and given joint consideration. The approach is illustrated in Figure 1.

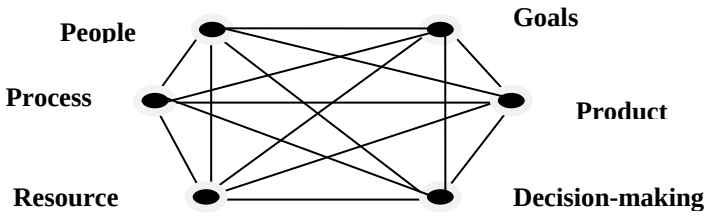

Figure 2 - A Socio-Technical Systems perspective (Adapted from Challenger et al. (2009))

The figure shows an organisation as a system comprising a wide range of interrelated factors, all in a state of dynamic interplay, with no particular sub-system taking automatic precedence over the other. Therefore, to enhance the success of the organisation, the whole system including for example, its people, work processes, product, goals, decision-making and resources should be viewed as interdependent and given joint consideration. In this way, the different factors that have impact and causal changes to the system can be observed, investigated and managed. It can also increase understanding on how other factors that emerge may affect the system. This understanding should provide a basis for manipulating the system to maximise its performance or delivery.

METHOD OF IDENTIFYING FACTORS CONTRIBUTING TO COMPLEXITY AND MULTI-PROJECT ENVIRONMENT

To identify all the factors contributing to project complexity and the challenges of the multi-project environment, extant literature was explored. Using an excel spreadsheet, all extant texts identified in the literature relating to factors or characteristics of complex projects, complexity, multi-projects, programmes, portfolio, and multi-project environment were listed. Coding was used to break down the contents of the textual materials into meaningful and pertinent units of information for analysis. The process included segmentation of the data in the extant texts followed by examination of the most frequent and significant characteristics of project complexity and multi-project environment to sort and synthesize them into theoretical themes emerging from data. By using this approach, any danger of forcing exception of important theoretical knowledge through preconceptions or terminology is removed (Bryant and Charmaz, 2007). Secondly, it aids the process of saturation, whereby following the analysis of literature, factors are added until they reach a point where no new ones are revealed, but just repeated.

FINDINGS

The results of the literature analysis showed that project complexity attributes can be categorised into process, people, goals and product whiles those factors which pose as

challenges to the multi-project environment as resource (availability, allocation and scheduling) and decision-making.

Table 2: Main Themes and factors of project complexity and multi-project environment

Area of Concern	Main Themes	Factors
Project Complexity	Process	Organizational and project structures
		No and variation of organizational / project management processes
		Planning and scheduling procedures
		Operational procedures
		Performance criteria
		Decision-making structures
		Procurement routes
		Change control procedures
	People	No of teams / department / clients / stakeholders / supply chain
		Diversity of stakeholders
		Relationships
		Team location
		Technical knowledge, expertise or experience
		Newness of team
	Goals	Goals definitions
		Outcomes
		Project objectives
		Organizational goals
	Product	No of elements
		No of technologies
		Newness / novelty of technology
		Type of product
		Location
		Scope definition
Multi-Project Environment	Resource availability, allocation and scheduling	Simultaneous management of throughput times, allocations and cost
		Allocation of scarce resource
		Dealing with resource queues
		Information
		Planning and control cycles
		Project times / programme schedules
	Decision-making	Hierarchical decision-making
		Coordination, interfacing
		Communication plan
		Prioritization
		Planning
		Organizational structure

Table 1 shows the main themes and the factors that emerged from the literature analysis. By integrating Figure 1 and Table 1, a framework is developed (Figure 2) for the research study. The individual factors will be investigated in a contractor's outfit to gain further understanding.

At this stage of the research, these factors are perceived to influence the delivery of complex projects in multi-project environment following the review of literature. However, these may be further refined following the response of semi-structured interviews with practitioners. The intention is that the whole system would be considered as a single, interrelated system, in contrast to many other organizational views which are limited by their origins and paradigms (Coakes *et al.*, 2002).

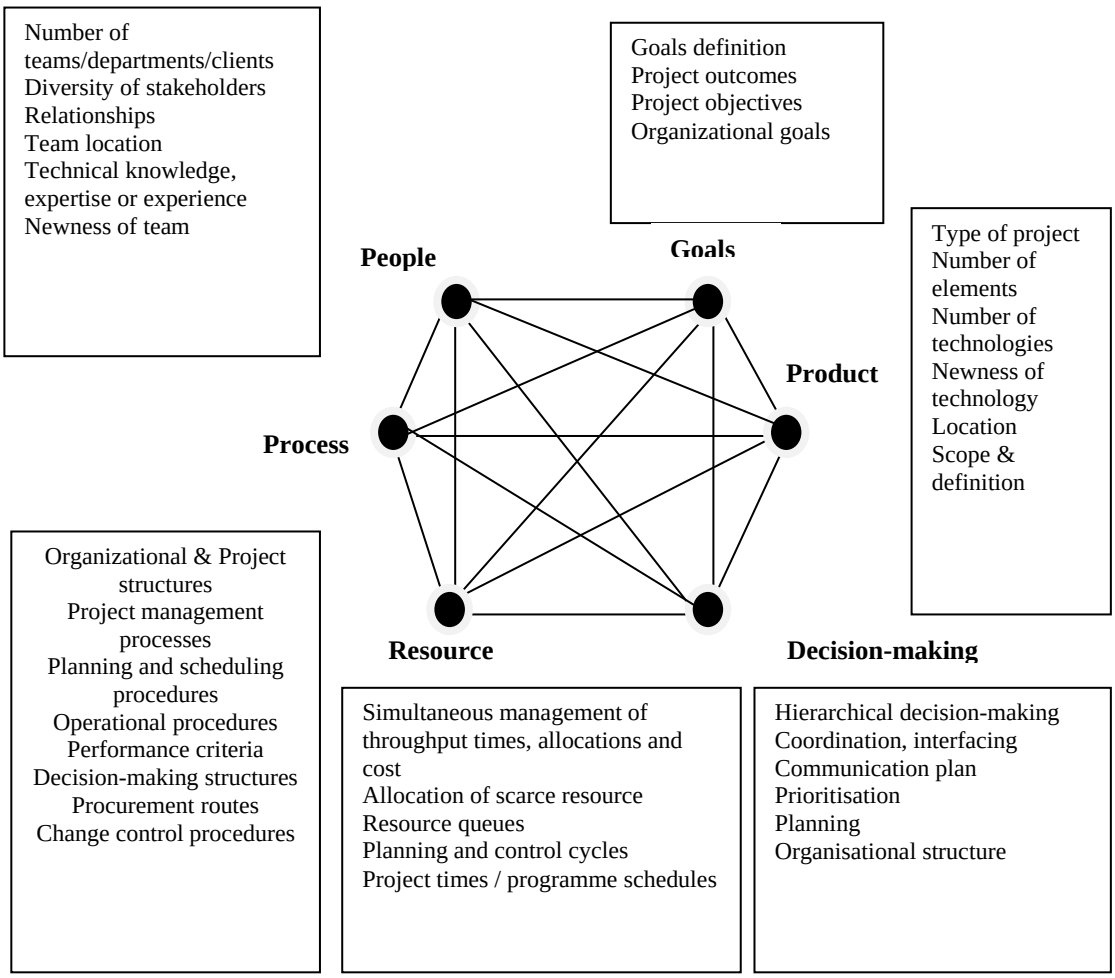

Figure 3: Themes and factors identified and integrated in a framework.

DISCUSSION AND CONCLUSIONS

The framework will be applied in an empirical context to investigate and establish the unique features of project complexity experienced by construction contractors. This will be done initially through a pilot case study using a series of semi-structured interviews with industry experts involved in delivering complex projects within contractor outfits. The integrated framework will also help to identify those variables that feature prominently in delivering complex projects within the multi-project environment of construction contractors. By this it will be possible to establish the focus of complex projects undertaken by construction contractors. Additionally, the framework will help to explore this focus for options to improve delivery. The results will provide an insight on the actual factors considered pertinent in complex project delivery, and also reflect the current focus of complex project delivery within construction companies. The identification of these factors should provide useful background from which key performance indicators and a framework for formulating delivery mechanism that can be developed for the construction contractor. Similarly, it should provide a means of studying the complex project delivery orientation of construction contracting companies in order to suggest areas of improvements which could bring about considerable benefit to their organisations. It therefore holds considerable potential for the managerial improvement of construction contractors.

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