



0263–7863(95)00093–3

The concept of project complexity – a review

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Reference to the project dimension of complexity is widespread within project management literature. However the concept of project complexity has received little detailed attention. This paper reviews the literature on project complexity relevant to project management, with emphasis towards the construction industry. The paper proposes that project complexity can be defined in terms of differentiation and interdependency and that it is managed by integration. Copyright © 1996 Elsevier Science Ltd and IPMA

Keywords: project complexity, organizational complexity, technological complexity, differentiation, interdependency, integration

Introduction

Complexity in construction projects

Construction projects are invariably complex and since World War II have become progressively more so. In fact the construction process may be considered the most complex undertaking in any industry¹. However, the construction industry has displayed great difficulty in coping with the increasing complexity of major construction projects².

Therefore an understanding of project complexity and how it might be managed is of significant importance. However, the concept of project complexity has received little detailed attention in project management literature. This paper reviews the literature on project complexity relevant to project management with emphasis towards the construction industry, and proposes a definition for project complexity.

Complexity and project management

Certain project characteristics provide a basis for determining the appropriate managerial actions required to complete a project successfully. Complexity is one such critical project dimension¹. As Bennett¹ observes, ‘‘practitioners frequently describe their projects as simple or complex when they are discussing management issues. This indicates a practical acceptance that complexity makes a difference to the management of projects’’. It is not surprising that complex projects demand an exceptional level of management and that the application of conventional systems developed for ordinary projects have been found to be inappropriate for complex projects³.

Hill⁴ states that the most important role of a production manager is the management of complexity. Furthermore,

the production of products or services of large scale or complexity is typically undertaken on a project basis⁴. Consequently, project-based management is frequently associated with the management of complexity.

The importance of complexity to the project management process is widely acknowledged, for example:

- Project complexity helps determine planning, co-ordination and control requirements^{5–9}.
- Project complexity hinders the clear identification of goals and objectives of major projects³.
- Complexity is an important criteria in the selection of an appropriate project organizational form^{1,3}.
- Project complexity influences the selection of project inputs, e.g. the expertise and experience requirements of management personnel⁶.
- Complexity is frequently used as a criteria in the selection of a suitable project procurement arrangement^{2,10}.
- Complexity affects the project objectives of time, cost and quality. Broadly, the higher the project complexity the greater the time and cost^{10–12}.

Defining complexity

Complexity—dictionary definitions

Dictionary definitions provide two basic dimensions of complexity relevant to projects:

- (i) Consisting of many varied interrelated parts

This meaning is neatly circumscribed so that project complexity can be operationalized in terms of: *differentiation* – the number of varied elements, e.g. tasks, specialists,

components⁷; and *interdependence or connectivity*—the degree of interrelatedness between these elements.

Interestingly the above interpretation of complexity mirrors systems theory in that a complex system is frequently defined in terms of differentiation and connectivity¹³. As projects can be viewed as complex systems, the above meaning for project complexity seems apposite.

(ii) Complicated, involved, intricate

This meaning of complexity is open to wide and diverse interpretation. For example, it can be interpreted to encompass anything characterized by difficulty⁶. Wozniak⁹ operationalizes project complexity based on nine diverse 'difficulty' factors such as: criticality of project, project visibility and accountability; clarity of scope definition. So this meaning of complexity has a subjective connotation implying difficulty in understanding and dealing with an object. Therefore, this interpretation of complexity is in the eyes of the observer^{2,13}. Interestingly, a subjective measure of complexity has been found to be an unreliable basis for research analysis^{12,14}. So, whereas this definition of complexity cannot be considered invalid, it does not provide a firm basis for the formulation of a concise and consistent standard. Furthermore, in many cases this meaning of complexity is better subsumed within the concept of uncertainty.

Project complexity—a proposed definition

It is proposed that project complexity be defined as 'consisting of many varied interrelated parts' and can be operationalized in terms of *differentiation* and *interdependency*.

This definition can be applied to any project dimension relevant to the project management process, such as organization, technology, environment, information, decision making and systems. So when referring to project complexity *it is important to state clearly the type of complexity being dealt with*. Unfortunately most project management literature fails to do this. It is worthwhile emphasizing that complexity is a distinctly different concept to two other project characteristics—size and uncertainty^{1,15,16}.

In order to elaborate upon the concept of project complexity as defined above, this paper will now deal with the two types of project complexity most commonly referred to in project management texts. That is, organizational complexity and technological complexity.

Organizational complexity

Introduction

The functions of a project organizational structure include: definition of relationships in terms of communication and reporting; allocation of responsibility and authority for decision making; allocation of tasks. Construction projects are typically characterized by the engagement of several separate and diverse organizations, such as consultants and contractors, for a finite period of time. This leads to the creation of a temporary multiorganizational structure to manage the construction project.

Organizational complexity—by differentiation

A complex organizational structure is one containing differentiated parts so that the greater the differentiation the

more complex the organization¹⁷. This differentiation has two dimensions:

(a) Vertical differentiation

This refers to the depth of organizational hierarchical structure, i.e. number of levels^{17,18}.

(b) Horizontal differentiation

This can be defined in two ways:

- (i) *Organizational units*: i.e. the number of formal organizational units, e.g. departments, groups^{5,6}.
- (ii) *Task structure*: this refers to the division of tasks. This division can be achieved in two basic ways¹⁸:
 - (a) *Division of labour*: tasks are structured so that non-specialists can perform them, thereby lessening the skill requirements in a single job position, e.g. assembly-line production.
 - (b) *Personal specialization*: this refers to work by specialists such as professionals, i.e. persons performing a wide range of activities, thereby increasing the task complexity of a single job position¹⁷. Therefore, organizational complexity by personal specialization is measured in terms of the number of different occupational specializations utilized to accomplish the work¹⁹. Each specialization represents a distinct area of knowledge typically founded upon education and/or training and the use of special tools and techniques¹⁹.

Personal specialization is prevalent in construction projects as a result of the wide variety of services required to carry out construction work¹⁷. Building projects belong to an 'adhocracy' organizational structure, i.e. high horizontal differentiation derived from professional and craft specializations^{15,20}. Complexity by personal specialization can be made more complex by having the specialists also differentiated by time and territory^{15,17}. That is, they work at different times during the project life cycle and/or at geographically separated offices. Such differentiation is typical in construction projects²².

Organizational complexity—by interdependency

Another attribute of organizational complexity in projects is the degree of operational interdependencies and interaction between the project organizational elements^{5,6,8}. Thompson²² defines the level of organizational complexity in terms of three types of interdependencies between organizational units—pooled, sequential and reciprocal. Reciprocal interdependencies represent the highest level of complexity and dominate the construction process²¹.

Technological complexity

The concept of technology

Many authors have highlighted the lack of consensus on a conceptual definition for technology^{8,16,23}. In particular the concepts of 'task' and 'technology' are frequently used interchangeably so that technology is commonly defined in terms of task performance.

Broadly, technology can be defined as the transformation processes which convert inputs into outputs²⁴. This

transformation process involves the utilization of material means, techniques, knowledge and skills^{15,16,24}. Technology can be divided into three facets: operations (equipping and sequencing of activities); characteristics of materials; characteristics of knowledge²⁵. The concept of technology can be applied to the project production system as a whole or the tasks performed by individual human beings²³; and at any level in the project organization, e.g. total organization, group, individual²⁶.

Technology is a multi-dimensional concept and can be categorized into two types: uncertainty and complexity²⁰. Many authors have operationalized technological complexity in terms of the difficulties of task performance^{6,12}. This opens the definition of technological complexity to wide and diverse interpretation so that, for example, it is defined in terms of a broad range of attributes such as building type, overlap of design and construction, difficulty of location, and interdependence of operations²⁷. Furthermore, it is submitted that difficulties of task performance are more often than not more appropriately allocated to the concept of uncertainty. So, it is proposed that technological complexity is more appropriately and usefully defined in terms of differentiation and interdependencies.

Technological complexity—by differentiation

Technological complexity by differentiation refers to the variety or diversity of some aspect of a task, such as:

- Number and diversity of inputs and/or outputs^{7,15,19,26}.
- Number of separate and different actions or tasks to produce the end product of a project^{1,4,11,19}. Actions can be regarded as separate when they are differentiated by technology, time or territory¹⁵.
- Number of specialities (e.g. subcontractors or trades) involved on a project¹⁰.

Technological complexity—by interdependency

Technological complexity by interdependency can encompass interdependencies: between tasks^{4,23}; within a network of tasks⁶; between teams¹; between different technologies⁶; and between inputs⁷. As with organizational interdependence, technological interdependence can be one of three types—pooled, sequential and reciprocal—with reciprocal interdependency the prevalent type in construction projects.

Integration

It is proposed that project complexity be interpreted and operationalized in terms of differentiation and interdependencies. There is a well-established body of knowledge asserting that differentiation and interdependencies are managed by integration, that is, by coordination, communication and control^{16,17,28,29}. The management function of integration is particularly important for construction projects as they are typified by strongly differentiated but largely interdependent components²². It is significant that integration has been claimed to be the *raison d'être* and essential function of project management^{22,30}. As Stuckenbruck³⁰ observed, “projects are complex . . . tasks; therefore, project managers must of necessity be very much aware of or even in some cases completely preoccupied with the problem of integrating their projects”.

Summary

Projects have certain critical characteristics that determine the appropriate actions to manage them successfully. It is submitted that project complexity — organizational, technological, informational, etc. — is one such project dimension. It is proposed that project complexity be interpreted and measured in terms of differentiation and interdependencies. The corollary to project complexity is integration by coordination, communication and control.

It is considered that the concept of project complexity is worthy of further consideration. The intention of this paper has been to provide a review of the theory on project complexity and to stimulate debate in the topic. As projects have become more and more complex there will be increasing concern about the concept of project complexity and its influence upon the project management process.

The next stage is to create an operational concept of project complexity and integration. Then projects can be analysed in order to ascertain whether there are correlations between the level of project complexity and the degree of integration.

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