PERGAMON

International Journal of Project Management 20 (2002) 425–436

INTERNATIONAL JOURNAL OF PROJECT MANAGEMENT

www.elsevier.com/locate/ijproman

Using systems dynamics to better understand change and rework in construction project management systems

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Received 20 November 2000; received in revised form 15 February 2001; accepted 17 April 2001

Abstract

The management of construction is complex enough without changes (e.g. to design/specification/client requirements), yet it is a familiar characteristic of in construction projects. To effectively manage change, project managers have to undertake detailed planning; to integrate the work activities of consultants, subcontractors and suppliers. In this context, changes are unplanned disturbances that (typically) interfere with the intended progression of work. Given this 'interference', what are the consequences of such disturbances on project performance and how can/do/should project managers deal with changes effectively? This paper describes how changes (and their actions or effects otherwise known as dynamics) can impact the project management system. Using a case study and the methodology of systems dynamics, the major factors influencing a project's performance are observed. The need for understanding of how particular dynamics can hinder the performance of a project management system are highlighted.

Keywords: Change; Project management; System dynamics; Dynamics; Rework; Variation

1. Introduction

Both the internal and external environments of construction projects are dynamic and relatively unstable. Changes that occur during a project's development may have significant and often unpredictable effects on its organisation and management. Thus, project managers must react appropriately to change and understand how it can influence the behaviour of the project system. Only then can changes be managed effectively.

Typically, project organisations comprise team members from different organisations who engage the project at different points in time to form a temporary multi-organisation [1], or an ephemeral shifting coalition [2]. Relationships between team members are governed formally by the contract(s) but are supplemented and moderated by informal understandings and protocol that have evolved over time; very often to cope with unforeseen difficulties. The latter characterise construction [3] and numerous studies [4,5] have identified these uncertainties. The nature of relationships within a project team is one of 'independent autonomy' with interdependence and uncertainty being inherent characteristics.

Project organisations are subject to an array of influences, from regulatory control to political and industrial intervention [6]. To deal with uncertainty, various tools and techniques (such as risk management) have been introduced; focussing on risk identification, risk analysis and risk response [7]. However, risk management assumes that risk factors can be identified and evaluated before they occur, and that necessary response strategies (or preventive methods) can be applied, particularly, through contractual arrangement [8]. In order to ascertain risk throughout a project's life cycle, a complete understanding of the complexity and dynamic nature of the construction environment is called for.

2. System dynamics

Idiosyncratically, a project organisation comprises of functionally interdependent entities; each striving to

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0263-7863/02/$22.00
PII: S0263-7863(01)00039-4

achieve a set of identifiable goals [2]. The composition of a project organisation can essentially be viewed as a system; so in the context of systems theory, the focus is upon how sub-systems interrelate to pursue and achieve these goals [9]. With this in mind, project management can be considered a sub-system, with planning, organising, controlling, and co-ordination of project activities, being inherent characteristics.

The inputs to this sub-system are identification and development of a client's objectives (e.g. utility, function, quality, time, cost), project resources (e.g. staff, materials, labour, plant, finance), and the formalisation of relationships between these variables. The ultimate system output is a completed project, which (hopefully) satisfies the client's objectives. Construction's dynamic environment means that the relationships between variables can be vicissitudinous in nature. Consequently, this may become a barrier to the project manager inasmuch as the project organisation's responsiveness to change may be inhibited by its organisational structure [10].

Building on the concept of systems and contingency theory, Stoner et al. [11] used the term *dynamic engagement* to describe the modern construction project management system. Stoner et al. suggest that managers need to re-think the way in which activities are performed in the face of unprecedented external changes. Dynamic engagement emphasises how managers react to change over time. By being able to understand the implications (of type and rate) of change, managers are better able to adjust to the environment within which they operate. Invariably, a project will experience changes (e.g. design changes and omissions) so resultantly, contingencies and construction buffers often represent a mechanism for anticipating such. When unexpected changes do occur, the planning, organising, motivating, directing, and controlling of construction can become an arduous and problematic task.

Construction project management (CPM) is a unique discipline with its own tools and techniques. Traditional control mechanisms (such as Work Breakdown Structure, Gantt Charts, PERT/CPM networks, Project Crashing Analysis, Trade-off Analysis, etc.) are not entirely adequate for managing complex projects. Many researchers have suggested the use of a system dynamics (SD) methodology in planning project activities [12–14] and determining the causes of rework in construction projects [10,15]. Additionally, a system dynamics methodology can improve decision-making at a strategic level. Rodrigues and Bowers [16] suggested that the management of projects could be categorised as follows:

1. *Level 1* — consideration given to the interactions of a specific project with the rest of the contractor company. The most important consideration here is whether the project objectives are compatible with overall company objectives.
2. *Level 2* — management is primarily concerned with strategic alternatives of an individual project. For example what are the major targets (milestones) and the form of organizational structure?
3. *Level 3* — here, specific details of a project's targets, activity schedules, manpower allocation, etc, are considered.

Traditional CPM tools and techniques are adequate for dealing with specifics in level 3, but are unable to fully address issues in levels 1 and 2. This is where SD can be used, to take a holistic view of the project management process. SD can focus on information feedback and offer a method for modeling and analyzing complex project systems [11]. A SD model can also incorporate technical, organizational, human and environmental factors [17], while simulating the behavior of major outputs of a project system over time. This paper describes how changes, actions or effects, otherwise known as dynamics, can impact the CPM system. Using case study examples and the SD methodology, major factors influencing a project's performance are investigated. The paper highlights a need for understanding how particular dynamics can hinder a construction project management system.

3. Dynamics of project management in construction

The dynamics that impinge upon a project system are derived from two basic sources: *planned activities* and *uncertainties*. Planned activities include the established operation programme, the arrangements of daily duties, planned material and plant operations, etc. These activities are designed to initiate change, that is, the progress of construction works.

In this paper *the dynamics of planned activities are called 'attended dynamics'*, which is synonymous with 'intended dynamics' a description often-used in SD literature. The term 'attended dynamics' is preferred because it assumes that an observed behavior is the direct result of active interventions. Attended dynamics can affect a project's objectives in either a positive or negative way. Positive influences would indicate that through policy intervention, progress had been made towards achieving a project's objectives. Conversely, negative influences would indicate that progress toward project objectives had been hindered. Similarly, *'unattended dynamics' otherwise known as 'unintended dynamics'*, places emphasis on factors beyond the control of project managers. Like attended dynamics, unattended dynamics can also have positive and negative influences. Uncertainties or unexpected events can significantly affect the operation of a project; such events either improving or hindering project performance. Both attended and unattended dynamics coexist throughout a project's life cycle.