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Project complexity and systems integration: Constructing the London 2012 Olympics and Paralympics Games

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Abstract

Our study of the London Olympics 2012 construction programme showed that systems integration is one of the major challenges involved in delivery of a complex – "system of systems" or array – project. Organizations cope with complexity by decomposing a project into different levels of systems integration with clearly-defined interfaces and buffers between levels and individual component subsystems. At the "meta systems integration" level, an organization has to be established with the capabilities to understand the total system of systems, manage external interfaces with the multiple stakeholder sand coordinate the integration of its component parts. At the "system integration" level, efforts are made to manage each individual system as a loosely-coupled, relatively self-contained subsystem with defined interfaces to coordinate interdependencies with other parts of overall array. Establishing processes to maintain stability whilst responding dynamically to uncertain and changing conditions is one of the most challenging aspects of systems integration.

Keywords: Managing projects; Managing programmes; Managing organization; Managing innovation; Engineering and construction

1. Introduction

Large-scale engineering, construction and infrastructure projects are complex and notoriously difficult to manage (Miller and Lessard, 2000; Scott et al., 2011). Despite the growing number of large-scale infrastructure projects executed around the world and opportunities to use lessons learnt to improve performance, most are late, over budget and fail to achieve their original objectives (Flyvbjerg et al., 2003; Morris and Hough, 1987). The term "megaprojects" is frequently used to describe the largest, most challenging and complex category of infrastructure projects involving investments of $1 bn or more in the construction of transportation, energy, water, waste and telecommunications infrastructure (Altshuler and Luberoff, 2003; Flyvbjerg et al., 2003; Van Marrewijk, 2007; Van Marrewijk et al., 2008; Sanderson, 2012). Although prior research emphasizes the size, risk, uncertainty, schedule urgency and institutional processes associated with megaprojects (Flyvbjerg et al., 2003; Miller and Lessard, 2000; Scott et al., 2011; Stinchcombe and Heimer, 1985) the concept of complexity receives little or no attention. This is surprising because megaprojects require an exceptional level of organizational and managerial capability because of their complexity.

We selected the London Olympics and Paralymics 2012 construction programme for our research setting because we had a rare opportunity to answer the following research question: How can an organizational structure and process be established to cope with a high degree of project complexity? The London Olympics is one of several high-profile infrastructure megaprojects conducted in the UK over recent years such as the Channel Tunnel Rail Link (High-Speed 1), Heathrow Terminal 5 and Crossrail projects. For many individuals and organizations involved, these projects were complex and difficult because they exceeded their prior experience and capabilities. Learning

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from other projects and relevant international experiences, new models have been established for delivering these complex projects based on flexible risk-sharing contracts, integrated project teams and delivery partner organizations (Gil, 2009; Davies et al., 2009.

The complexity of a project can be defined as a system in terms of the number and variety of components and interdependencies among them (Baccarini, 1996; Dvir et al., 1998; Hobday, 1998; Hughes, 1998; Shenhar, 2001; Shenhar and Dvir, 1996, 2007; Williams, 1999). Components produced by numerous different organizations have to be integrated into a functioning system. The integration challenge is greatest when components are in reciprocal interdependence (Thompson, 1967); a situation found in complex projects where the actions of each party must be mutually adjusted to the actions of other parties (Morris, 2013). Several studies have identified systems integration as the core organizational capability required to deal the interdependency, uncertainty and change found in complex projects (Hughes, 1998; Morris, 1994; Prencipe et al., 2003; Sapolsky, 1972; Sayles and Chandler, 1971). The systems integrator coordinates the network of organizations involved in the phases of design, construction, integration, testing, commissioning and handover of a fully operational system. It comprehends how components and subsystems interact when joined together in a complete system, manages the uncertainty caused by their integration and balances the need for stability and flexibility when plans have to be adjusted and conditions change.

Our study of the London Olympics helped us to identify the core systems integration capabilities required to deal with the most complex type of project – a "system of systems" composed of an array of individually complex systems joined together to achieve a common system goal. Our findings suggest that organizations cope with complexity by decomposing a project into different levels of systems integration with clearly-defined interfaces and buffers between levels and individual component subsystems. At the "meta systems integration" level, the client or sponsor responsible for the project faces a number of choices about how to establish a systems integrator with the capabilities to understand the total system, manage external interfaces with the multiple stakeholders and coordinate the integration of its component parts. Meta systems integration can be performed in-house by a large client, an experienced prime contractor or joint-venture delivery partner established on a temporary basis and disbanded on completion of the project. At the "system integration" level, efforts are made to manage each individual system as a loosely-coupled, relatively self-contained subsystem with defined interfaces to coordinate interdependencies with other parts of the overall array. Establishing processes to maintain stability whilst responding dynamically to uncertain and changing conditions is one of the most challenging aspects of systems integration. Standardized, consistent and carefully planned processes which serve to freeze components of a system into a given position have to be unlocked to introduce the mutual adaptation required to deal with change.

The paper is divided into the following sections. In a review of the literature, Section 2 identifies systems integration as a structure and process created to coordinate multiple organizations and deal with the reciprocal interdependency found in complex projects. Section 3 introduces the methods used and the case study and analysis of the London Olympics construction programme is presented in Section 4. Section 5 discusses the role of systems integration as a structure and process for coping with project complexity and concludes by suggesting some promising avenues for future research.

2. Conceptualizing project complexity

2.1. System complexity, interdependence and integration

Efforts to define the complexity of projects often refer back to systems theory and the idea that an organization can be treated as a complex system of interacting component parts (Boulding, 1956; Simon, 1962; Von Bertalanffy, 1968). Component subsystems are interacting because the behaviour of one component depends on other components. Interactions occur at different levels in a hierarchical system: among subsystems (inter-component linkages) and interactions within subsystems (intra-component linkages). Using the metaphor of a building, Simon (1962) suggests that outside walls insulating the building from the environment represent the boundary of the system. The internal rooms and walls between them define the boundaries and interactions among subsystems. The partitions dividing each room into cubicles define the boundaries and interactions within subsystems. In a "nearly decomposable system", interactions among subsystems are only weakly connected because the behaviour of each component is more independent – or insulated – from other components (Simon, 1962).

Subsequent research distinguished between tight or loosely-coupled interactions in the design, production and operation of complex systems (Perrow, 1984; Weick, 1976). A tightly-coupled system has little or no slack or buffers among its component parts because the behaviour of one component (e.g. a design change) directly affects what happens in other components. A loosely-coupled system is nearly decomposable because the behaviour of each component is less dependent on other components; it can be modified or adjusted without directly affecting other components.

Influenced by systems thinking, early contributions to contingency theory argued that organizations – including project and matrix structures – can be viewed as systems designed to deal with different environments (Burns and Stalker, 1961; Galbraith, 1973; Lawrence and Lorsch, 1967; Mintzberg, 1983; Thompson, 1967; Woodward, 1965). Organizations are segmented into differentiated units (e.g. design, engineering, production and marketing) with specialized functional knowledge, working styles, differing points of view and behaviour. Lawrence and Lorsch (1967) argued that each part of an organization is designed to deal with a part of the external environment and linked together by an "integrator" to promote collaboration and resolve conflicts required to achieve an organization's objective. Complex projects are often difficult to coordinate and have to devote considerable resources to integration because they have highly differentiated cross-functional structures involving in-house units and multiple parties (Galbraith, 1973; Morris, 2013: 58).