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

**Andrew Davies* and Ian Mackenzie****

*School of Construction and Project Management
The Bartlett Faculty of the Built Environment
University College London
1-19 Torrington Place
London WC1E 7HB

**Innovation & Entrepreneurship Group
Imperial College Business School
Imperial College London
South Kensington Campus
London SW7 2AZ

*Corresponding author:
Tel: +44(0)20 3108 3073
Email: a.c.davies@ucl.ac.uk

## 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, manage external interfaces with the multiple stakeholders and 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.



**Key words:** 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, Levitt and Orr, 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 (Morris and Hough, 1987; Flyvbjerg, Bruzelius and Rothengatter, 2003). The term "megaprojects" is frequently used to describe the largest, most challenging and complex category of infrastructure projects involving investments of $1bn or more in the construction of transportation, energy, water, waste and telecommunications infrastructure (Altshuler and Luberoff, 2003; Flyvbjerg et al, 2003; Marrewijk, 2006; Marrewijk, Clegg, Pitsis and Veenswijk, 2007; Sanderson, 2012). Although prior research emphasizes the size, risk, uncertainty, schedule urgency and institutional processes associated with megaprojects (Miller and Lessard, 2001; Flyvbjerg et al, 2003; Scott et al, 2011) 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 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, Gann and Douglas, 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; Shenhar and Dvir, 1996; Hughes, 1998; Williams, 1999; Dvir, Lipoveskey; Shenhar and Tishler, 1998; Hobday, 1998; Shenhar, 2001; Shenhar and Dvir, 2007). 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 (Sayles and Chandler, 1971; Sapolsky, 1972; Morris, 1994; Hughes, 1998; Prencipe, Davies and Hobday, 2003). 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 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; 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: 473).

Subsequent research distinguished between tight or loosely-coupled interactions in the design, production and operation of complex systems (Weick, 1976; Perrow, 1984). 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; Woodward, 1965; Lawrence and Lorsch, 1967; Thompson, 1967; Galbraith, 1973; Mintzberg, 1983). 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).

Building on Thompson (1967: 54-55), project management scholars suggest that interdependencies among differentiated parts of a project can be pooled, sequential or reciprocal (Baccarini, 1996; Williams, 1999; Morris, 2013). In pooled interdependency, each part provides a discrete contribution to the project, irrespective of other parts. This occurs in a loosely-coupled, nearly decomposable system where tasks can be performed in isolation by one party without impairing the activities of other parts of the project. In sequential interdependency, one organization's output becomes an input for another part because there is a direct serial relationship between tasks (e.g. time-sequence project scheduling tools). In reciprocal interdependency "each unit involved is penetrated by the other" (Thompson, 1967: 55) and the outputs of each unit become inputs for others. This occurs in a tightly-coupled system where tasks performed by organizational units have to be modified to match the actions of others (e.g. concurrent engineering to perform related tasks in parallel). All projects have pooled interdependency, some have sequential and pooled, and the most complex projects have reciprocal, sequential and pooled (Morris, 2013; 57).

…………………………..
Insert Figure 1 about here
…………………………..

Thompson (1967) helps us to identify three mechanisms of coordination or integration for addressing project interdependencies (Morris, 2013) (see Figure 1). Integration by standardization establishes the internally consistent rules, relatively stable routines and processes required to deal with pooled interdependency. It ensures that actions taken by one part or phase of the project are consistent with others. Integration by planning creates carefully-defined schedules to govern the actions of sequentially interdependent parts of a project, match the activities of multiple parties in advance and manage changes in specifications and requirements against defined goals and schedules. Project planning tools define interdependent tasks in a network diagram and determine the overall pace of the programme and measure its progress against dynamically changing conditions (e.g. PERT or Critical Path Method). Planning ahead of time helps to prevent known problems from happening and identifies the contingency needed for dealing with them when they do occur. Integration by mutual adjustment involves gathering new information, working collaboratively and responding to emergent, unforeseen problems in real-time. Mutual adjustment and rapid adaptation is important in large, urgent and complex projects where parties are in reciprocal interdependence (Morris, 2013: 57).

## 2.2 Project complexity and uncertainty

Hirschman (1967) was among the first scholars to treat projects as temporary systems of interacting components. He recognized that the complexity challenge is not size itself, but the difficulty of establishing a structure and process to coordinate, adjust and fit together the parts into a coherent whole and respond dynamically to unpredictable interdependencies and changing conditions over a defined period of time. More recent project management research also builds on systems theory to define projects in terms of the number of differentiated components (or "system size"), the interactions (or degree of interdependencies) among them and their arrangement in the hierarchical structure (Hobday, 1998; Gholz, 2003; Davies and Hobday, 2005; Sommer and Loch, 2004; Loch, DeMeyer and Pich, 2006; Shenhar and Dvir, 2007). The outcome or product of each project comprised of different combinations of hardware, software and intangible services is treated as a hierarchical system composed of a number of interacting components, subsystems and entire systems.

Projects can be classified according to increasing degree of complexity ranging from relatively simple components and subsystems to more complex systems and system of systems projects. A component (e.g. radio base station) can often be undertaken in-house by a functional department or cross-functional project team, whereas more complex systems (e.g. an aircraft or airport) require a network of suppliers coordinated by a large organization – such as a prime contractor or joint-venture – reliant on formal, elaborate and bureaucratic processes of reporting and control.

Despite efforts to distinguish clearly between them, the concepts of complexity and uncertainty are connected. Uncertainties range from a known or foreseeable event whose impact on the project can be anticipated in advance to entirely unforeseen events with unpredictable consequences (Loch et al, 2006). Although the progress of each component or subsystem can often be anticipated, it is difficult to predict how components will interact when joined together as a system because of the interdependence of components and uncertainty caused by their coordination requirements (Saposky,1972: 252).

Complex projects contain several internal sources of uncertainty. First, the introduction of new technology into a project increases the possibility that it will be late, over budget and fail to achieve its original specifications (Shenhar 1993). Such technological uncertainty may be reduced by integrating tried and tested components and freezing the design as early as possible. When new technology is incorporated in a project the "integrator has to cope with unrecognized or ill-defined interfaces and the endless changes that have taken place in the specifications" (Sayles and Chandler, 1971: 258). Second, the novelty or uncertainty of the project's outcome on completion of a project at a future point in time is associated with difficulties in defining user requirements and customer needs up front (Loch et al, 2006; Shenhar and Dvir, 2007). Third, the urgency or criticality of the time available to complete the project is a source of temporal uncertainty. The predictable conditions found in routine projects can be planned well in advance, whereas more urgent and time critical projects depend on rapid and mutual adaptation in response to dynamically changing and unpredictable conditions (Eisenhardt and Tabrizi, 1995; Shenhar and Dvir, 2007). Pace can be "time-based" when planned actions are initiated by temporal milestones, benchmarks and schedules and "event-based" when mutually adjusted actions are initiated by events (Gersick, 1994). Project pace creates the sense of urgency, shared goals and strategic focus required to help coordinate multiple parties, control the process and manage uncertainty (Grabher, 2002; Jones and Lichtenstein, 2008).

External sources of uncertainty are associated with the fact that tasks performed in complex projects are affected by the action of other elements, organizations and stakeholders in the environment within which a system is conceived and delivered (Hughes, 2004; Geraldi, Maylor and Williams, 2011; Scott et al, 2011). The concept of "extended systems" refers to the interactions with broader social, political and communities affected by these projects (Morris and Hough, 1987; 212). External uncertainties include the status or profile of the project, support from different stakeholders, alignment or divergence between stakeholder interests, the transparency or openness of project participants, and behavioural aspirations of human actors involved or impacted by the project. The risk of social misalignments, cultural differences, ecological damage or political conflicts makes a complex project uncertain and particularly when they are "situated in urban or semi-urban areas and tend to have considerable social, environmental, and distributive impacts (Scott et al, 2011: 46).

### 2.3 Complex projects and systems integration

To understand the challenges involved in the integration of multiple and interdependent components it worthwhile revisiting studies of large-scale systems during the Cold War. Several authors emphasize the importance of systems integration as the core organizational structure and process required to manage the integration of complex weapons and aerospace projects such as ballistic missiles (Atlas, Titan and Polaris) and Apollo moon landing missions (Sayles and Chandler, 1971; Sapolsky, 1972; Morris, 1994; Hughes, 1998; Sapolsky, 2003; Gholz, 2003). Systems integration is now widely used to coordinate the design and production of complex products, systems and infrastructure in military and civil markets (Hobday, Davies and Prencipe, 2005). Systems integration is a separate task from component and subsystem development and manufacturing. A systems integrator has to understand how components and interfaces are designed fit together in the whole system. It coordinates and controls the network of contractors and suppliers involved in the design of components and subsystems, construction of physical components and subsystems, and integration, test, commission and handover of a fully operational system (Brusoni, Prencipe and Pavitt, 2001; Prencipe et al, 2003;; Davies, Brady and Hobday, 2007). The systems integrator must "nurture the in-house capability…to know more about the total effort than any of the contracting parties" (Sayles and Chandler, 1971: 319).

Systems engineering and project management capabilities are required to conceive, design and coordinate the development and deployment of large-scale systems involving multiple disciplines and many participating organizations (Sapolsky, 2003). Systems engineering emphasizes interoperability: the requirement that each component or subsystem works in concert with other components or subsystems. Components are carefully defined with “clean interfaces”, integrated into a functioning system and tested to detect unexpected interactions so that the system performs as originally intended when it goes into operation with the final user. Project management emerged as a managerial discipline alongside systems engineering to ensure that the process of integration is well planned and multiple parties involved are coordinated throughout the project life cycle (Johnson, 2003).

The systems integrator relies on formal contractual agreements, shared goals, planning and persuasion to encourage the close cooperation between diverse parties involved in supplying component parts of a system, addressing interdependencies among them and accomplishing system-wide goals (Sayles and Chandler, 1971). A process has to be established to control how changes in the design of one component impact on other components. Designs change frequently during the early development of a complex project and only slowly become “stabilized” as engineers and managers solve problems (Johnson, 2003: 42). By “freezing” the design, the systems integrator prevents further changes in that part of the system. Subsequent changes have to be communicated to all affected parties and approved by a “change control board”.

Systems integrators have to make tradeoffs in the interest of system-wide goals rather than the interests of organizations that design or produce the system. Organizations involved in supplying a component may have an incentive to hide some information from oversight efforts, fearing that full disclosure of information might for example lead to the renegotiation of fees (Gholz, 2003: 292). The systems integrator must encourage parties to report data in favourable ways to avoid giving a biased picture of progress. They have to “penetrate” other organizations, establish processes to increase the “visibility” of a neglected component or ill-defined interface and encourage parties involved to uncover the problem and take the action needed to solve it (Sayles and Chandler, 1972).

Building on prior research (Gholz, 2003), we can identify two main levels of systems integration in complex projects (see Table 1). At a lower level of complexity, “system integration” combines various components and subsystems jointly performing multiple functions into an entire system or platform to meet a specific client's requirements (e.g. aircraft, weapon system, communications network or building construction) including services (e.g. maintenance, training, support and product upgrades) provided during the operational life of a system. Rarely undertaken by a single organization, component and subsystems suppliers are typically coordinated by a prime contractor responsible for defining user requirements, product definition, systems integration, testing and verification.

…………………………..
Insert Table 1 about here
…………………………..

At a higher level of complexity, "system of systems integration" joins together a dispersed and large-scale array of platforms and systems, each with a specific purpose, to achieve a common goal (e.g. an airport, urban mass transit system, the English Channel Tunnel or a national missile defence system). These array projects are often spread over a wide geographical area, developed over time as new systems are added in an evolutionary way and comprised of a great variety of systems and platforms projects. Often organized as programmes, array projects are usually coordinated by "an umbrella organization that deals mainly with the financial, logistical, and legal issues and is responsible for contracting and controlling the offices of the systems projects that make up the array" (Shenhar and Dvir, 2007: 105). While large and experienced clients or prime contractor organizations can be appointed to coordinate array projects, temporary joint-venture organizations – such as a special purpose vehicle – are often established to represent the interests of the client and gain access to a broader base of capabilities than one organization alone can provide.

Previous research concentrates on the system level (Prencipe et al, 2003; Hobday, Davies and Prencipe, 2005; Davies and Hobday, 2005; Davies et al, 2007; Shenhar and Dvir, 2007), but rarely addresses system of systems integration (an exception is Davies, Gann and Douglas, 2009). We call this "meta systems integration" because it depends on the ability to preside over and understand all of the system of systems well enough to make tradeoffs and reach decisions in the interest of overall system goals. One of the biggest challenges is that a system of systems crosses so many organizational boundaries. The different customer organizations and stakeholders involved have strong independent identities, often conflicting interests, motivations and priorities for scheduling and allocating funding. Each organization will try to influence the development of the system of systems by pushing for their preferred definitions of systems specifications and user requirements (Gholz, 2003: 298). Figure 2 illustrates the differences between system integration and meta systems integration.

…………………………..
Insert Figure 2 about here
…………………………..

**3. Research aims and methods**

Our research examined the organization and process established to deliver the London Olympics 2012 construction programme. The case was selected because it represented a high degree of project complexity. Undertaking a single case study provides a theoretically sound way of studying the process and context of organizational change (Pettigrew, 1990). As long as it is carefully chosen, a case can be used to develop generalizations about how things work which may be appropriate and valid for a larger number of samples (Flyvbjerg, 2006). We classified the construction of the Olympics as a system of systems/array project and examined the organizational structure and processes used to coordinate the overall system, each individual system and interdependencies between them.

Rather than seeing the informants and practitioners involved in our research as data collection sites, we worked closely with them – using an engaged scholarship approach (Van de Ven, 2007) – by participating in workshops and meetings to explore the research problem, review relevant literature and identify the concepts required to understand how an organization can be established to deal with complexity. We gathered data through interviews and official documents, presentations, contracts, baseline reports, the trade press (e.g. Institution of Civil Engineers, 2011; New Civil Engineer, 2011). Interviews were undertaken between December 2010 and September 2011 during the final stage of construction and handover to LOCOG (the London Organising Committee of the Olympic and Paralympic Games) responsible for preparing for and staging the Games. Interviews – each typically a minimum of one hour in length – were conducted with 32 senior managers, such as the chairman, CEO, directors, project managers, project sponsors and project directors (see Appendix A). To maintain anonymity we refrain from referring to interviews with named individuals and have placed several "power quotes" in table so that their comments remain non-attributable.

Our interviews were undertaken in two phases to understand the structure and processes established to manage the two levels of integration: the system of systems (the programme level) and individual systems contracts (the project level). In the first phase of interviewing, we focused on the management and structure of the overall programme with interviews conducted within the Olympic Delivery Authority (ODA) who acted as the client for the programme and CLM – the temporary joint venture between CH2MHill, Laing O'Rourke and Mace – which was formed specifically to act as the ODA's "delivery partner". The interviews focused on how the ODA and CLM worked together as an umbrella organization and meta systems integrator to oversee, coordinate and integrate each project within the overall programme. In a second phase of interviewing, our focus shifted to five specific system projects identified by key interviewees to address the complexity of different systems projects including: the Olympic Stadium, the Velodrome, the Aquatics Centre, Athletes Village, International Broadcast Centre (IBC)/Media Press Centre (MPC) and largely temporary structures (Basketball, Handball and Eton Manor). Interviews with the ODA project sponsor and the CLM project manager were complemented with interviews with the relevant Tier 1 principal contractor (project director). The interviews addressed the ways in which each individual project fitted within the overall programme, whilst being tailored to meet specific systems needs and circumstances.

We produced summaries of each interview and coded them to address the organizational action required to deal with different dimensions of complexity including the segmentation of the project into component parts and interdependencies among them. Interview findings were used to produce six short embedded case studies of the challenges involved in delivering the permanent and temporary venues projects. A manuscript analysing the entire construction programme, including the individual system projects, was made available and read by several senior interviewees to check, validate and verify our findings.

## 4. Case study of a complex project: constructing the London 2012 Olympics

This section presents our case study findings and analysis of the London 2012 Olympics construction programme.

### 4.1 Project characteristics

London was awarded the 2012 Olympic and Paralympic Games on 6th July 2006. The promise of creating a lasting legacy for London was key to winning the bid and influenced the approach used to design and construct the venues and connecting infrastructure. The ODA was set up in 2006 as a temporary client and public sector organization responsible to oversee the design and construction of the Olympic Park infrastructure, venues, Olympic Village and transport systems. It was responsible for handing over the Olympic venues to the London Organising Committee of the Olympic Games and Paralympic Games (LOCOG), the private sector organization responsible for staging the Games. Planning permission for the Olympic Park was secured in October 2007 and construction started in May 2008.

The project life cycle was divided into six phases:

- Year 1 (2006-2007): this phase handed over the 600 acre Stratford site to the ODA
- Year 2 (to Beijing 2008): the “demolish, dig and design” phase prepared the site for the “big build” phases
- Year 3 (to 27 July 2009): the “big build” (foundations) phase prepared for the construction of Olympic Park infrastructure and venues
- Year 4 (to 27 July 2010): the “big build” phase (structures)
- Year 5 (to 27 July 2011): the “big build” phase (completion)
- Year 6 (to 2012): the phase was a year of testing in the run up to the Games

The final cost of £6.8bn was well within the original £8.1bn allocated to construct the programme and completed on time in July 2011, 13 months before the games started on 27th July 2012, providing LOCOG with sufficient time to test the venues and use the feedback from the trials to prepare for the Games. The construction programme consisted of over 70 individual projects (planned, approved and managed by principal contractors) including 14 temporary and permanent buildings, 20km of roads, 26 bridges, 13km of tunnels, 80 hectares of parkland and new utilities infrastructure. The major venue projects were clustered on the Olympic Park (Olympic Stadium, Aquatics Centre, Velodrome, IBC/MPC media centre and Athletes Village), many of which were individually large, high-cost and complex. All venues were connected by new infrastructure including utilities networks, roads, bridges, energy centre and pumping stations. Olympic Park is the size of London's Hyde Park and a quarter of the size of Beijing's Park with the same number of venues. As an indication of the scale of task, 12,635 people worked on the Olympic Park and Olympic Village during the peak period of construction at the end of March 2011. A summary of the permanent and temporary venues which we studied in our research is provided in Table 2.

…………………………..
Insert Table 2 about here
…………………………..

In the following case study, it is helpful to distinguish between the programme and projects. Large and complex projects are often broken down into many individual subprojects and managed as a programme. A programme refers to the managerial approaches used by organizations to achieve a strategy, vision or defined goal by coordinating the diverse interests and priorities between interrelated projects (Maylor, Brady, Cooke-Davies and Hodgson, 2006; Pellegrinelli, Partington and Geraldi, 2011). Where appropriate we use the term programme to describe the array of interrelated projects involved in constructing the venues and infrastructure. We use the term project to refer to specific system such as the Olympic Stadium project and Velodrome project. Each principal contractor was responsible for managing its own chain of subcontractors. For example, Carillion's IBC/MPC project involved 50 Tier 1 and 50 Tier 2 suppliers. The rest of this section provides an in-depth analysis of the structure and process established to construct the London Olympics.

### 4.2 Complexity, systems integration and interdependency

The organizational structure established to construct the Olympics venues and infrastructure was arranged in two interacting levels of systems integration to match the complexity of the project (see Table 3). The task of meta systems integration was undertaken jointly by the ODA and CLM. Performing the role of client, the ODA established the goals of the programme, worked closely with the delivery its partner to plan the programme, monitored progress against those goals, and provided a single interface between the overall system and its external environment. CLM was appointed as delivery partner and systems integrator for the programme and interfaces with individual projects.

Principal contractors were responsible for integrating and delivering individual system projects (venues and infrastructure) against time, cost, quality and other strategic objectives and assisting in the coordination of interfaces with adjacent systems. The suite of contracts used on the Olympics programme were designed to support clearly-defined procedures and forge the collaborative relationships between the ODA, CLM and PCs required to deal with unpredictable, ill-defined interfaces and changing conditions found within and between each project. Figure 3 shows the relationship between project and programme levels and Figure 4 provides a simplified view of the different levels of systems integration used on the London Olympics.

…………………………………………..
Insert Figures 3 & 4 and Table 3 about here
…………………………………………..

*4.3.1 Meta systems integration: the client*

After winning the Olympics bid the ODA faced the challenge of integrating a large-scale and complex system of systems in a densely-populated part of a major city. The Olympic Park had to be constructed and available for use by a fixed date across a constrained site involving multiple systems which became increasingly interconnected as more venues were constructed. At the same time, the ODA had to engage with many stakeholders and institutional interests associated with the programme such as government, local authorities, railway authorities and local community groups involved in shaping the programme and defining its outcomes.

As the client responsible for delivering the programme, the ODA considered the idea of assuming in-house responsibility for systems integration, but soon recognized the difficulties it would face in attempting to attract people with experience, skills and knowledge needed to manage such a challenging programme:

> "We obviously appointed CLM because with the best will in the world, going through as a public sector organization we could not recruit world class individuals as quickly as possible going through the route of public procurement" (ODA interview).

The ODA originally considered appointing a large prime contractor (e.g. Bechtel) for programme management and multiple contractors for project management. But after some consideration decided that a new joint-venture organization established as a "clean sheet of paper" was required to deal with the complexities involved in delivering the construction programme, whereas it was felt a prime contractor might be unwilling to change, explore alternatives or abandon its established routines. David Higgins, the ODA's Chief Executive, believed that the systems integrator should encompass the broad-based capabilities required to manage the programme and interface individual system projects. This role would have to be performed by a delivery partner organization bringing together firms with a track record in the successful delivery of large and complex programmes and projects (Hone, Higgins, Galloway and Kintrea, 2011: 7). Table 4

The ODA's competitive tendering process emphasized "compatibility of working style" and "capability to deal with problems". CLM was selected as the preferred international consortium and delivery partner for the programme. Each partner in this special purpose vehicle brought distinctive capabilities, experience and complementary assets. The US firm CH2M Hill had a track record as a programme manager and an ability to integrate component parts of complex projects, including previous Olympic construction projects. Laing O'Rourke and Mace successfully worked together as major contractors on the £4.3bn Heathrow Terminal 5 – one of the largest and complex recent UK projects. Laing O'Rourke had strong capabilities in construction delivery and Mace was renowned for its expertise in project management. Ian Galloway, recruited from Bechtel to lead CLM, was the only CLM employee; all other CLM staff were contractually connected to their parent companies. By appointing CLM, the ODA could tap into the skills and expertise found in three large firms which it needed to manage different phases of the project. At its peak, CLM employed around 600 staff. If the 250 ODA staff are included, the overall programme management cost around 10% of the programme expenditure.

The task of meta systems integration was divided between the ODA and CLM (see Table 4). The relationship between the two organizations is clarified by one manager:

> "ODA was a thin, intelligent client and, you know, a lot of our job was about, you know, helping, sort of, set up the machine and then almost create the space around the machine, the big delivery machine" (ODA interview).

The ODA concentrated on dealing "upwards" by establishing a single interface between the overall project and the often conflicting interests of around 750 stakeholders including the London's Mayor, sporting bodies, LOCOG, Greater London Authority, five London boroughs, International Olympic Committee and British Olympic Association. CLM was responsible for keeping the ODA fully informed about the progress of the project measured against the schedule, managing “downwards” across the overall programme and acting as project manager in collaboration with principal contractors on each major construction project.

The ODA and its assurance team participated in media and parliamentary enquiries, obtained financial support and sought government approval for any significant proposed changes in scope. Under the ODA’s leadership, the delivery partner and principal contractors were driven by the primary time and cost objectives of the programme, but expected to achieve a number of secondary objectives published as six priority themes (see Appendix B), such as sustainability and health and safety. The ODA published a strategy for each of them, including specific objectives and principles applied across the programme, cascading down from CLM to principal contractors and beyond.

…………………………..
Insert Table 4 about here
…………………………..

*4.3.2 Meta systems integration: delivery partner*

The division of meta systems integration tasks allowed the ODA to provide oversight and assurance for the programme and gave the CLM the autonomy needed to manage the programme and projects. The ODA acted as a buffer protecting its delivery partner from outside “interference” added to the system by external stakeholders which could make integration more difficult. Our analysis of different levels of systems integration performed by the ODA, CLM and principal contractors (PC) is illustrated by quotations from our interviews in Table 5. CLM worked as a “consultant” for the ODA with an amended NEC3 Professional Services Contract. This collaborative form of contract provided CLM with incentives to meet various milestones and targets and aligned the objectives of the ODA and CLM, and between CLM and the principal contractors (e.g. CLM and Lend Lease on the Athletes Village project).

…………………………..
Insert Table 5 about here
…………………………..

The ODA and CLM had to find a way of working collaboratively and openly as virtually integrated organization during the planning, design, construction and handover of the venues to LOCOG. The relationship between the two organizations adjusted over time to address the changing requirements and different phases of the programme. Joint review meetings held throughout the programme served to align their organizational models, capabilities and resources (Hone et al, 2011: 7). In the start-up planning phase when the ODA and CLM were first established, they were co-located in an off-site location to build a team between the client and delivery partner and align their strategic objectives, processes and culture. CLM directors formed part of the ODA's executive management team. Forging a relationship based on trust and openness was facilitated by holding joint team events and social activities. When the programme moved from planning into design and construction, a decision was made not to co-locate ODA and CLM organizations. The core ODA team continued to work at the planning head office in Canary Wharf, whereas the CLM team moved to the various construction offices on site at Stratford. When CLM co-located with Tier 1 suppliers, the core organizational linkage shifted to the CLM and contractor levels of the system. This geographical separation of the central ODA organization and CLM teams reflected the new division of tasks. The ODA performed the role of client and project sponsor and CLM worked to achieve overall programme outcomes and ensure that each project was delivered against defined goals.

Acting as the client's programme and project manager, CLM managed each individual contract, administered the change control process and provided assurance that each principal contractor was achieving its targets and keeping pace with the programme. Its main challenge was establishing a structure to manage the meta systems integration process:

> "If you take the components we have on the Olympic park individually, there's probably nothing overly complex; if you put them all together, that's where the complexity is. That's really meant that we've had to focus a lot of our time and effort, on integration" (CLM interview).

CLM created layered structure to manage different levels of systems integration:

> "Make sure you have the ability to manage integration. Integration is a huge huge…This is about management and integration, and flexing all the different layers. So, you had this layer cake of how we would approach the whole project programme. So, it's really about how you structure – it's all about structuring and how you're going to deliver things" (CLM interview).

Different phases of integration were managed during the life of the programme including design, construction and operational handover. Digital technologies and software tools were established to coordinate each phase of integration (e.g. Project Wise and Project Documentation Management System). In the design phase, CLM had to manage interdependencies between adjacent projects. A “Design Interface Schedule” system showed how a design change in one part such as a venue impacted on other parts of the programme. In the construction phase, CLM attempted to simplify the integration process by dividing the management of systems into relatively self-contained “vertical” buildings (the permanent and temporary venues) and interconnected “horizontal” infrastructure (utilities, roads and bridges):

> “On most development sites you build the infrastructure, then you build the vertical buildings. Here they tried to do the infrastructure and the vertical building simultaneously, so that’s why integration has been a challenge... ideally we would, some of the infrastructure projects we would have liked to have had finished earlier” (CLM interview).

In the operational handover phase, CLM was “pulling the whole thing together to make sure it operates as one” (CLM interview).

CLM established standardized processes, reporting procedures and documentation tools to coordinate the overall programme and interdependencies between systems. Vertical procurement of the buildings created a buffer around each system project, which helped to define and limit the number of interfaces with other systems and infrastructure. As one manger put it: “So you drop a cylinder over it and say everything inside that cylinder belongs to the PC [principal contractor]” whereas “infrastructure has all been procured horizontally” (CLM interview). Each contractor could focus on its task of designing and integrating specific systems because “In venues they get their own area - so you can make your contractor king of their island, if you like, though not many of them are islands” (CLM interview). The Olympic Park surrounding these islands was divided into four zones and teams of engineers and managers were responsible for understanding:

> “How each of the areas of the park would be integrated together… there’s all the integration that goes around making the park work…But then you sit at the end of it with a massive kit of parts, and it creates a huge integration problem” (CLM interview).

With so many system projects occurring simultaneously and in sequence on a constrained site, the most frequently occurring situations and problems from start to finish were associated with "integration" (Hansford, 2010). The reciprocal interdependency between systems was about:

> "The complexity of inputs and the complexity and the understanding of the inter-relationship between those inputs. And what is one contractors' input is another contractor's output. It's a system approach" (CLM interview).

Despite efforts to limit the number of interactions and minimize interface problems, all of the systems were interconnected and some projects such as infrastructure works had interfaces with every other part of the park. As one manager explained, CLM:

> "Have broken it down into its components. But obviously there is a degree of managing those interfaces between the contractors, so they do all touch each other, and where their scope ends, the next one begins" (CLM interview).

CLM created an integration process to identify how slippages or changes in one venue or connecting infrastructure (e.g. water and energy supply) impacted on others. CLM established "programme integration" group and organized "integration committees" to manage the park as a complete system, with interfaces between 15-20 contractors working at any particular time. The CLM integration group originally functioned as a central organization with the oversight required to understand how all the components fitted together. As the programme moved towards completion, the group operated in a more decentralized way as construction progressed to deal with issues at the individual project level.

…………………………..
Insert Tables 5 & 6 about here
…………………………..

*4.3.3 System integration: principal contractors*

Meta systems integration processes and tools were applied consistently across the programme, whereas the integration of each system (e.g. the Velodrome and Olympic Stadium) was planned and managed relatively independently by a principal contractor. The ODA used a variety of NEC3 contracts with the principal contractors to address the specific requirements, challenges and complexity of each project. Contracts for individual venues were held by the ODA and CLM managed the individual contractors and connections between them. Project delivery was finalized when the accepted programme was agreed with the principal contractor responsible for individual systems, including the work breakdown structure, schedule, milestones and risk allocation.

Under this contractual approach, principal contractors were encouraged to exploit their own distinctive capabilities and prior experience to create solutions tailored to the requirements of specific venues and infrastructure:

> "We were given the freedom to determine how we were going to deliver the targets that the ODA were setting. And we all do things slightly differently because of the circumstances we found ourselves in, it's largely driven by the nature of the venue and program issues and suppliers and so on" (PC interview).

Principal contractors were expected to find their own way of meeting individual targets and schedules for their project and implementing the ODA's Priority Themes such as the Health and Security theme. Risks were reduced by appointing principal contractors and coalitions of subcontractors with tried and tested capabilities developed by working together on previous complex projects.

Individual system projects largely corresponded to a single venue such as the Velodrome or a component of the system-wide infrastructure (e.g. utilities). The projects ranged in complexity from the iconic Aquatics Centre with its unique roof design to the relatively standardized, modular and reusable systems used to build the Athletes Village and temporary venues. For example, whereas on the Athletes Village the project team preformed "one thing 3,000 times", on the Aquatics Centre there were few opportunities for standardization because the team did "3,000 things once" (Stimpson, 2011). The most complex projects (Aquatics Centre, Velodrome and Olympics Stadium) were procured using versions of NEC3 Option C (target price with pain/gain), a form of target cost contract to promote collaboration and the flexibility to expose issues and face known risks, deal with unexpected situations and explore opportunities to improve performance. Each project had its own contingency fund and contractors were incentivized to deliver projects within agreed target costs. Venue projects based on less complex designs and standardized reusable components (e.g. IBC/MPC) were procured using more traditional NEC3 Option A (fixed price) Design and Build contracts. The procurement strategy for the Athletes Village eventually used a combination of Construction Management and Design and Build contracts. A "Managed Package" was appropriate for the temporary venues (basketball, water polo and Eton Manor) given that their unusual requirements were less attractive to conventional contractors used to building venues, but not dismantling them. CLM assumed role of principal contractor and project manager for the temporary venues and let the work out as packages to a list of framework contractors for engineering, construction, modular buildings, temporary seating and fit out.

Integrating individual projects into the overall array had to be carefully managed. The independence and autonomy of principal contractotrs had to be preserved, whilst encouraging the collaboration and responsiveness needed to deal with interdependencies with adjacent venues and common infrastructure. As one of the principal contractors explained:

> “We’re an island site but there are still interfaces. For example, the bridges contracts were really tricky for CLM and the contractor and they were really tricky for us because we had some awkward interfaces at the end of the bridges. We had literally one man working on bridges interfaces for a year, and that was closely interfaced with the CLM design managers. So there were certain areas where we interfaced closely, where the external technical review teams had to do their stuff. We interfaced closely on that” (PC interview).

Dealing with such reciprocal interdependencies could not be addressed by one organization on its own. It required the continuous interaction, and penetration of, all affected parties. The ODA and CLM appointed representatives to work closely on site as part of co-located, integrated project teams with principal contractors. The pairing of an ODA executive (project sponsor) and CLM executive (project manager) applied across all the system projects (and bundles of smaller projects). The ODA project sponsor was responsible for defining the project goal, securing approval for the project business case and managing stakeholders. The ODA sponsor worked with the CLM delivery partner manager, who was responsible for working with the principal contractor to deliver the project against programme objectives.

### 4.4 Systems integration: balancing stability and change

The ODA and CLM created standardized, stable and consistent process to coordinate the development of multiple systems, minimize unexpected interactions and respond flexibly to deal with problems that might hinder progress of the individual project and the overall programme. A balance had to be struck between stability and change:

> “You can’t have constant change, there have to be fixed points where things that have been completed and issued to others to work to. If you change after that date, and that then means that another contractor has to change what they’re supplying to accommodate that, then they

could have a cost, so making it clear that this is your cost now to this contractor to make changes after the agreed completion date, you know, your design is frozen, if you want to change it, they have a compensation that may end up being deducted from your contract value" (CLM interview).

Those elements that could be firmly fixed at the beginning were forced by the programme's deadline, funding constraints, the physical requirements of site and capacity of systems. Carefully-prepared plans, schedules and deadlines guided the performance of the delivery partner and principal contractors, helped to anticipate risks in advance and mitigate them when they occurred. Programme management processes ensured that tasks performed in one part of the project were predictable and consistent with those undertaken by organizations working in other parts. Emergent events, interface problems and unfolding situations that could not be foreseen in advance depended on the capability of the organizations involved to respond flexibly and rapidly to change (see Table 6).

…………………………..
Insert Table 6 about here
…………………………..

The pace, planning and scheduling of the London Olympics programme was dictated by an "immoveable deadline". The project was time-critical because the games had to open on 27th July 2012. The ODA and CLM recognized that although the construction schedule could not be manipulated, a realistic budget and secure contingency was needed to cope with the risks and uncertainties surrounding the project. The original budget of £2.4bn was insufficient and after six months of work by the ODA and CLM the final budget was announced in Parliament in March 2007. It was set at £9.3bn and included a contingency of £1.2bn. The ODA's budget for construction was £8.1bn. The CLM strategic planning team established a baseline definition of the detailed scope, budget, schedule, risk and interfaces of the programme which was published as the 500-page "Yellow Book" in November 2007. This document was revised and published as the "Blue Book" in November 2009 to account for the numerous changes in scope that had occurred since the original publication.

The baseline documents became the main point of reference for scheduling the work to be done on the programme and individual projects and monitoring how the budget was spent during construction. The construction programme was divided into four yearly phases, with milestones published for each year. Building most of the venues ahead of schedule introduced some temporal contingency into the programme. Annual phases were translated into more specific target objectives and milestones for the individual systems, setting out clearly how each project was expected to perform against the overall programme schedule. Deadlines published online and therefore subject to public scrutiny provided an added incentive to avoid schedule slippages.

The ODA and CLM established a monitoring and assurance process to ensure that each project provided detailed, regular and accurate information on progress in terms of budget, scheduling and performance. This process helped to increase the visibility of unexpected problems, ill-defined interfaces or changes in specifications. Monthly reports provided information to measure progress, forecast costs and changes in schedule, scope or budget using an early warning "traffic light" tracking system to identify issues in order of importance. Issues flagged as red or amber were identified in monthly meetings by the programme team, but dealt with at the project level. When emergent issues were identified, the project teams would estimate the additional costs and time needed to solve them. An assurance process was established to avoid schedule slippages associated with the introduction of change. The ODA was responsible for challenging individual project teams and monitoring the performance of CLM and the principal contractors. Monthly trend reviews involving the ODA and CLM allowed senior managers to identify trends which might not be apparent at lower levels.

A highly-structured change control process was established to uncover, report and document problems hindering progress, provide vital information about integration problems and poorly performing or neglected parts of the system and make the changes required to keep the programme on track. Any significant change proposed by the principal contractor had to have CLM's and the ODA's approval. At the end of each month, project teams reported any changes to the "Change Control Board" chaired by the ODA chairman. During the early phase of the programme, as many as 45 people in a room would discuss monthly reports. This number gradually reduced to as few as 6 people as the programme reached completion. This change control process "flushed things up to the surface quickly so you could address and deal with them" (ODA interview).

Dealing with unforeseen problems depended on intense collaboration among the contracting parties and "an organizational culture that was highly-action oriented" (Hone et al., 2011: 8):

> "I think it was really the dynamic of having enough, you know, good people, excellent people with a real attitude of, you know, rapid assessment and decision making, be able to see issues, discuss them, make decisions and move on" (ODA interview).

The ODA and CLM "wanted to work by persuasion and by consensus, but from a position of strength" (ODA interview). The use of workshops and informal meetings to build consensus around problems and solutions helped to achieve and maintain a close alignment of ODA and CLM over time. As another manager emphasized: "I always tell my guys is, anybody can manage the steady state; when things go wrong, it's about how we solve problems together – contractually, commercially, co-operationally" (CLM interview). Working in close proximity in co-located project teams over an extended period of time fostered the shared understanding, trust and openness required to identify emergent problems at an early stage and strive collaboratively to find innovative solutions:

> "Management action has been very much about how we make a decision, right or wrong. It might all sound simple, this, but the complexity of what we're working with has been very changeable. So, that's worked well. It's getting the visibility" (CLM interview).

Several examples from our study of systems projects illustrate how parties involved identified problems, adjusted their plans and responded flexibly to unexpected and dynamically changing situations. First, ISG, the principal contractor responsible for the Velodrome, identified an opportunity to reduce costs and save time by changing the roof design from a steel to a "cable net" roof. After some consideration, CLM agreed to this radical change to the original design, including incurring the risk of purchasing 13,500m of cables before the design was finalised. The ODA provided time to evaluate the proposal and ultimately accepted the change even though it exacerbated short-term time pressures. In an attempt to shift the risk to the principal contractor, the ISG's contract was changed from target price with pain/gain to fixed-price. The cable net roof took only nine weeks to construct rather than the six months for the steel roof. Second, as a result of the economic downturn in late 2008 private funding was no longer available to pay for two systems: the Athletes Village and the IBC-MPC. The ODA's decision to switch to public funding triggered a re-appraisal of design and encouraged the principal contractors and CLM to develop lower-cost schemes. In the original plan, for example, the Athletes Village would have been built by the private sector and leased to LOCOG for the Games. The ODA solved the problem by using contingency money and other savings on the programme to fund construction of the Village and recover the money by selling the development after the Games. The ODA renegotiated Lend Lease's contract and most of the buildings were procured with the principal contractor using a lump-sum, design and build contract. Third, as principal contractor responsible for the Aquatics Centre, Balfour Beatty gained the ODA's approval to change the roof design from a tied arch structure to one using single span trusses so that it could introduce a more efficient method of construction without altering the roof's iconic shape. Fourth, facing the possibility of a significant overspend, McAlpine, the principal contractor for the Olympics Stadium, decided to re-engineer the original design to reduce costs and save time. As a result, the contractor managed to build the stadium within budget (close to £496m) and over two months ahead of schedule.

### 4.5 Complexity and context

A number of contextual factors shaped the programme and added to its complexity such as status of the project, pressures to succeed and the economic crisis of 2008 which called for new approaches to funding and the allocation of risk. As Sir John Armitt, the ODA's Chairman, emphasized the "Olympic project is the most high profile that you could imagine" (Kortekaas, 2012) and a significant factor facilitating the overall progress of the programme was the so-called "Olympics effect" (Mackenzie and Davies, 2011). A desire not to avoid the poor performance of recent public projects – such as the heavily over budget and delayed Wembley football stadium – and the fact the Olympics was the world's most prestigious sporting event fostered a widespread attitude that this was "a once in a lifetime opportunity, so you don't want to get it wrong, because if you do, it'll be apparent to everyone in the industry. That's quite a motivator" (CLM interview).

## 5. Discussion and conclusions

We selected the London Olympics because it provided an opportunity to understand how an organizational structure and process can be established to cope with a high degree of complexity. The view that a project can be treated as a temporary system of complex and interacting components arranged in hierarchical structure encouraged us to revisit early organizational studies inspired by systems thinking (Simon, 1962; Hirschman, 1967; Perrow, 1984) and contingency theory (Lawrence and Lorsch, 1967; Thompson, 1967). These studies argue that organizations cope with complexity by breaking a system down into smaller component parts and coordinating interdependencies between and within components.

Building on these ideas, project management research suggests that a project can be considered a temporary system of interacting hardware, software and knowledge-based intangible components (Hobday, 1998; Davies and Hobday, 2005; Loch et al, 2006; Shenhar and Dvir, 2007). Project complexity is defined in terms of the number of components, degree of interactions among them and the number of hierarchical levels in the system. Complex projects are inherently uncertain because of the inability to predict how components interact when joined together (Sapolsky, 1972; Geraldi et al, 2011). Internal sources of uncertainty are associated with new technology, novelty for users, and temporal urgency of the project. External sources refer to the social, political and ecological conditions and variety stakeholders which together form the environment within which a complex project is embedded.

Referring an early stream of literature, we argued that systems integration is the structure and process required to address different degrees of project complexity (Sayles and Chandler, 1971; Sapolsky, 1972; Morris, 1994; Hughes, 1998). A systems integrator has the engineering and project management capabilities in-house to coordinate interdependent tasks performed by the multiple parties involved in the design, production, integration and handover of a complex system. Subsequent research has suggested that systems integration applies to complex projects across many different industries including construction and the built environment (Prencipe et al, 2003). Our study of the London Olympics showed that systems integration is one of the major challenges involved in delivery of a complex project. But what generalized principles can we learn from the experience of a single case study which will apply to each and every special-case of a complex project? We recognize that there are “no magical management system cures” (Sapolsky, 1972: 253) and no “single predictable managerial strategy” (Sayles and Chandler, 1971: 317) will serve the needs of every complex project.

Our findings show that organizations attempt to cope with complexity by decomposing a project into different levels of systems integration with clearly-defined interfaces and buffers between and within individual component systems. A system of systems project can be divided into levels of systems integration to cope with such a high degree of complexity – in our case a large, time-critical system of systems project in a densely populated urban area involving multiple stakeholders.

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 and coordinate the integration of its component parts. 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. Few organizations have the capabilities in-house to address all aspects of systems integration and the joint-venture delivery partner approach is receiving increasing attention around the world as a possible model for managing complex megaprojects. A version of this approach is being used to programme manage the UK's £14.8bn Crossrail high-capacity suburban railway project connecting the East and West of London. The ODA considered all three options before deciding to appoint a dedicated delivery partner bringing together organizations with the prior experience and the complementary capabilities required to understand the total system and design, integrate and coordinate the many organizations involved in this complex project.

The meta systems integration task was divided between the client and its delivery partner. The client was responsible for achieving the overall programme goals and managing upwards and outwards to external stakeholders. By dealing with all external interfaces between the system and the external environment, the client created an "umbrella" or buffer insulating the delivery partner and principal contractors from the frequent and potentially disruptive interventions of numerous stakeholders. A delivery partner organization was established to represent the interests of the client and create the common processes required to coordinate the overall programme and interdependencies between each project as a tightly-coupled system.

At the system integration level, the overall array can be decomposed into smaller more manageable subsystems. The design, construction and operational handover of each system is managed as a loosely-coupled system with clearly-defined interfaces with other systems within the overall array. In our research, principal contractors and their own network of subcontractors were appointed to deliver individual systems. Whereas the client and delivery partner established standardized processes and clearly-defined budgets and schedules to keep the programme on track, flexible contractual arrangements encouraged principal contractors to find their own routes to achieving specific project goals and devise processes tailored to the requirements and complexity of each project. The delivery partner and client participated in co-located integrated project teams with principal contractors to provide the penetration of collaborating organizations required to coordinate interdependencies with adjacent or affected systems and to ensure that the progress of each system project was aligned to overall system-wide goals of the programme.

But as Sayles and Chandler (1972) recognized, efforts to cope with complexity can never eliminate uncertainty: "In complex projects managers learn to expect the unexpected, that what looks good today may be in deep trouble tomorrow" (Sayles and Chandler, 1971: 311-312). Establishing processes to maintain stability whilst responding dynamically to unforeseen 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 may have to be unlocked to introduce change and adapt to unexpected situations. To retain its options in the face interdependency, uncertainty and change, a systems integrator must apply what Sapolsky (1972) calls "disciplined flexibility": the discipline to work within the predictable constraints of the system and determination to meet schedules and the flexibility to avoid a premature commitment to a particular goal and adapt to changing and emergent situations (Sapolsky (1971: 250).

In our research, the meta systems integrator established standardized programme management processes, carefully-defined baseline plans, detailed schedules of activities and to freeze the programme as far as possible, including the budget and contingency available for dealing with uncertainty and change. Planning to achieve deadlines ahead of time created some contingency or temporal buffer to prevent overall progress from being held back by poorly performing systems. A highly structured change control process has to be established to "unlock the frozen positions" and promote rapid, mutual adaptation when conditions change (Sayles and Chandler, 1971: 271). To gain the collaboration needed to uncover problems and identify solutions, the meta systems integrator established integration processes to identify and address system-wide problems and worked collaboratively with principal contractors in integrated project teams to uncover and solve problems or respond to opportunities to innovate and improve performance.

This paper is limited to a single case and more research is needed to understand how systems integration is required to deal with project complexity. We recognize that complexity depends on the capabilities of individuals and organizations involved, some of which will be engaged in projects which exceed their prior experience (Morris and Hough, 1987: 14). The context surrounding each project also has implications for its managerial style and organizational culture. In our study, for example, participating in a highly prestigious project played an important role in creating a collaborative, highly motivated multi-party organization focused on tackling such a complex and difficult task. While difficult to undertake because of the long duration and resources needed to study megaprojects, future research could benefit from comparative studies exploring the relevance of some of our initial propositions about project complexity and systems integration including the type of systems integrator organization, levels of systems integration and processes required to balance between stability and change over time. Although is it is widely assumed that large, complex and high-risk engineering megaprojects cannot easily be broken down in modular components (Miller and Xavier, 2001: 97), we believe that understanding how they can be "nearly decomposed" and integrated to cope with complexity is a promising and potentially rewarding area of research.

**References**

Altshuler, A. and Luberoff, D. 2003. Mega-projects: The changing politics of urban public investment, Washington: The Brookings Institution.

Baccarini, D. 1996. The concept of project complexity – a review, International Journal of Project Management, 14(4): 201-204.

Boulding, K.E. 'General systems theory – the skeleton of science', Management Science, 3(2): 197-208.

Brady, T. and Davies, A. 2010. From hero to hubris: reconsidering the project management of Heathrow's Terminal 5. International Journal of Project Management, 28: 151-157.

Brusoni, S., Prencipe, A., and Pavitt, K. (2001), Knowledge specialization and the boundaries of the firm: why do firms know more than they make?, Administrative Science Quarterly, 46: 597-621.

Burns, T., and Stalker, G.M. (1961). *The management of innovation.* Oxford: Oxford University Press.

Davies, A. and Hobday, M. 2005. The business of projects: managing innovation in complex products and systems, Cambridge: Cambridge University Press.

Davies, A., Gann, D. and Douglas, T. 2009. Innovation in megaprojects: systems integration at Heathrow Terminal 5. California Management Review, 51(2): 101-125.

Davies, A., Brady, T. and Hobday, M. 2007. Organizing for solutions: systems seller vs. systems integrator', Industrial Marketing Management, Special Issue: 'Project marketing and marketing solutions', 36:183-193.

Dvir, D., Lipoveskey, S. Shenhar, A. and Tishler, A., 1998. In search of a project classification: a non-universal approach to success factors, Research Policy, (27): 915-935.

Eisenhardt, K. M., and Tabrizi, B.N. (1995). Accelerating adaptive processes: product innovation in the global computer industry, Administrative Science Quarterly, 40: 84–110.

Flyvbjerg, B., Bruzelius, N. and Rothengatter, W. 2003. Megaprojects and risk: an anatomy of ambition. Cambridge: Cambridge University Press.

Flyvbjerg, B. 2006. Five misunderstandings about case-study research. Qualitative Inquiry, 12/2: 219-245.

Galbraith, J.R. 1973. Designing complex organizations. Reading, MA: Addison-Wesley.

Geraldi, J., Maylor, H. and Williams, T. 2011. Now, let's make it really complex (complicated). International Journal of Operations and Production Management, 31/9: 966-990.

Gersick, C.J.G. 1994. Pacing strategic change: the case of a new venture. Academy of Management Journal, 1: 9-45.

Gholz, E. 2003. Systems integration in the US Defence Industry, 279-332 in Prencipe, A., Davies, A. and Hobday, M. 2003. The business of systems integration, Oxford: Oxford University Press.

Gil, N. 2009. Developing cooperative project-client relationships: how much to expect from relational contracts?. California Management Review, 51(2): 144-169.

Grabher, G. 2002. Cool projects, boring institutions: Temporary collaboration in social context, Regional Studies, 36: 245-262.

Hansford, M. 2010. Race to the finish, New Civil Engineer, 22-29 July 2010.

Hirschman, A.O. 1967, Development projects observed, Washington: The Brookings Institution.

Hobday, M. 1998. Product complexity, innovation and industrial organization, Research Policy, 26: 689-710.

Hobday, M., Davies, A. and Prencipe, A. 2005. 'Systems Integration: A Core Capability of the Modern Corporation', Industrial and Corporate Change, 14:1109-1143.

Hone, D., Higgins, D., Galloway, I. and Kintrea, K. 2011. Delivering London 2012: organisation and programme, Proceedings of the ICE – Civil Engineering, 164(5): 5-12.

Hughes, T.P. 1998. Rescuing Prometheus, New York: Pantheon Books.

Institution of Civil Engineers. 2011. Delivering London 2012: planning and people. Civil Engineering, Special Issue, May 2011, 164/1: 1-66.

Jones, C. and Lichtenstein, B.B. 2008. Temporary inter-organizational projects: How temporal and social embeddedness ehance coordination and manage uncertainty, pp231-255 in Cropper, S., Ebers, M. Ring, P.S. and Huxman, C. (eds). Handbook of Interorganizational Relations, Oxford: Oxford University Press.

Johnson, S.B. 2003. Systems integration and the social solution of technical problems in complex systems, 35-55 in Prencipe, A., Davies, A. and Hobday, M. 2003. The business of systems integration, Oxford: Oxford University Press.

Kortekaas, V. 2012. Olympics contractors build on experience, Financial Times, 15 February 2012.

Lawrence, P.R. and Lorsch, J.W. 1967. Organization and environment: managing differentiation and integration, Boston, MA: Harvard Business School Press.

Loch, C.H., De Meyer, A., and Pich, M.T. 2006. Managing the unknown: a new approach to managing high uncertainty and risk in projects. New Jersey: John Wiley and Sons.

Mackenzie, I. and Davies, A. 2011. Lessons learned from the London 2012 Games construction project, London Olympics Learning Legacy, ODA 2011/269 www.london2012.com/learninglegacy

Maylor, H., Brady, T.B., Cooke-Davies, T. and Hodgson, D. 2006. From projectification to programmification, International Journal of Project Management, 24: 663-672.

Miller, R., and Lessard, D.R. 2000. The strategic management of large engineering projects: shaping institutions, risks, and governance. Cambridge, Mass: The MIT Press.

Miller, R. and Olleros, X. Chapter 4 'Project shaping as a competitive advantage', pp93-112 in Miller, R., and Lessard, D.R. 2000. The strategic management of large engineering projects: shaping institutions, risks, and governance. Cambridge, Mass: The MIT Press.

Mintzberg, H. (1983). Structures in fives: Designing effective organizations. Englewood Cliffs, NY: Prentice Hall.

Morris, P.W.G. and Hough, G.H. 1987. The anatomy of major projects: a study of the reality of project management, Chichester: John Wiley and Sons.

Morris, P.W.G. (1994). The management of projects, London: Thomas Telford.

Morris, P.W.G. (2013). Reconstructing Project Management, Chichester, Wiley-Blackwell.

New Civil Engineer. 2011. Major project report: delivering the UK Games. February 2011: 1-20.

Pellegrinelli, S., Partington, D. and Geraldi, J.A. 2011. Program management: an emerging opportunity for research and scholarship, chapter 10 in Morris, P.W.G., Pinto J.K. and Söderlund, J.(eds) The Oxford Handbook of Project Management, Oxford: Oxford University Press.

Perrow, C. 1984. Normal accidents: living with high risk technologies, Princeton University Press.

Pettigrew, A. 1990. Longitudinal field research on change: theory and practice. Organization Science, 1/3: 267-292.

Pich, M.T., Loch, C.H., and De Meyer, A. 2002. On uncertainty, ambiguity and complexity in project management, Management Science, 48 (8): 1008-23.

Prencipe, A., Davies, A. and Hobday, M. 2003. The business of systems integration, Oxford: Oxford University Press.

Sanderson, J. 2012. Risk, uncertainty and governance in megaprojects: a critical discussion of alternative explanations, International Journal of Project Management, 30: 432-443.

Sapolsky, H.M. 1972. The Polaris system development: bureaucratic and programmatic success in government, Cambridge, Mass: Harvard University Press.

Sapolsky, H.M. 2003. Inventing systems integration, 15-34 in Prencipe, A., Davies, A. and Hobday, M. 2003. The business of systems integration, Oxford: Oxford University Press.

Sayles, L.R. and Chandler, M.K. 1971. Managing Large Systems: Organizations for the Future', New Brunswick: Transaction Publications.

Scott, W.R., Levitt, R.E. and Orr, R.J. 2011. Global projects: Institutional and Political Challenges, Cambridge: Cambridge University Press.

Shenhar, A.J. 1993. From low- to high-tech project management, R&D Management, 23(3): 199-214.

Shenhar, A. J., and Dvir, D. 1996. 'Toward a typological theory of project management.', Research Policy, 25: 607-632.

Shenhar, 2001. One size does not fit all projects: exploring classical contingency domains, Management Science, 47/3: 394-414.

Shenhar, A. J. and Dvir, D. 2007. Reinventing project management: the diamond approach to successful growth and innovation. Boston, Mass: Harvard Business School Press.

Simon, H.A. 1962. The architecture of complexity, Proceedings of the American Philosophical Society, 106(6):467-482.

Sommer, S.C. and Loch, C.H. (2004), Selectionism and learning in projects with complexity and unforeseeable uncertainty, Management Science, 50(10): 1334-1347.

Stimpson, J. 2011. Vital venues delivered to order, New Civil Engineer, Major Project Report: Delivering the UK Games, February 2011.

Stinchcombe, A.L. and Heimer, C. 1985. Organizational theory and project management: Administering uncertainty in Norwegian offshore oil, Oslo: Norwegian University Press.

Thompson, J. D. 1967. Organizations in action: social science bases of administrative theory, McGraw-Hill.

Van de Ven, A. 2007. Engaged scholarship: a guide to organizational and social research. Oxford: Oxford University Press.

Van Marrewijk, A. 2007. Managing project culture: the case of Environ megaproject, International Journal of Project Management, 25: 290-299.

Van Marrewijk, A., Clegg, S.R., Pitsis, T. and Veenswijk, M. 2008. Managing public-private megaprojects: paradoxes, complexity and project design, International Journal of Project Management, 26: 591-600.

Von Bertalanffy, L. 1968. General systems theory: foundations, development, applications, George Braziller.

Weick, K. 1976. Educational organizations as loosely coupled systems. Administrative Science Quarterly, 21/1: 1-19.

Williams, T.M. 1999. The need for new paradigms of complex projects. International Journal of Project Management, 17(5): 269-273.

Woodward, J. (1965). *Industrial organization: theory and practice*. Oxford: Oxford University Press.

## Figures and Tables

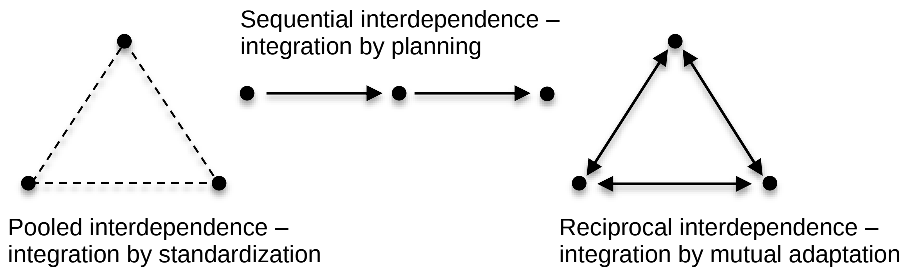


**Figure 1: Systems interdependence and integration**
(Morris, 2013)

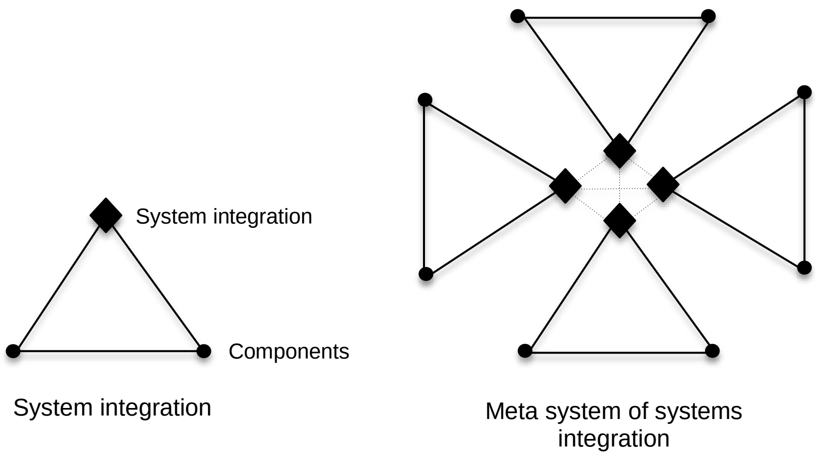


**Figure 2: Levels of systems integration**

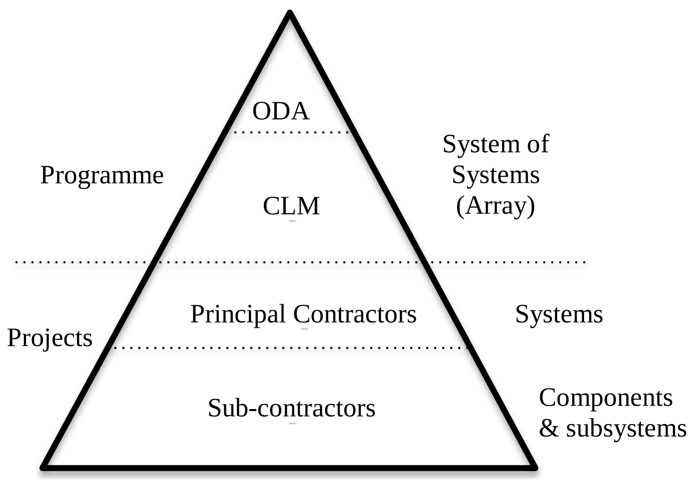


**Figure 3: London 2012 Olympics: programme, projects and systems**

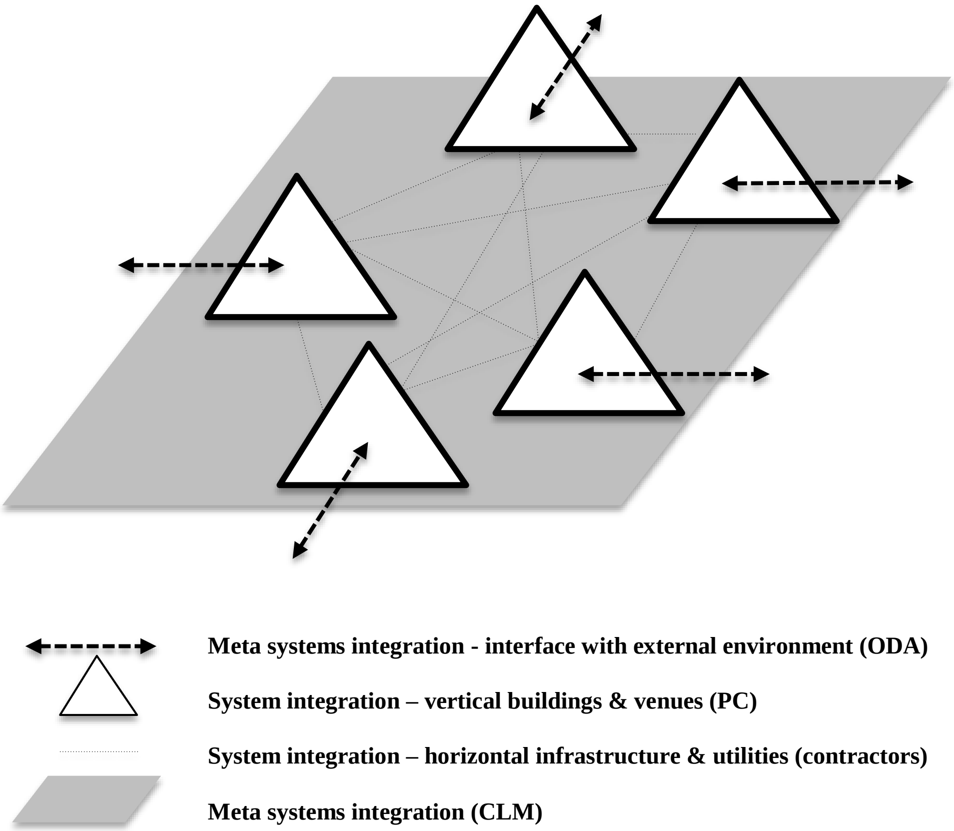


**Figure 4: Simplified view of systems integration on the London 2012 Olympics**

| | System integration | Meta systems integration |
|---|---|---|
| **Definition** | Integrate various components and subsystems, jointly performing multiple functions' into an entire system or platform to meet a specific operational requirement | Integrate a dispersed and large-scale array of platforms and systems, each with a specific purpose, to achieve a common goal |
| **Project complexity** | System, platform | System of systems, array |
| **Examples** | Aircraft, weapon system, communications network or single building construction | Airport, urban development, mass transit system, the English Channel Tunnel or a national missile defence system |

**Table 1: Levels of systems integration and complex projects**

| Major systems | Principal contractor | Suite of contracts | Key characteristics |
|---|---|---|---|
| | | **Permanent structures** | |
| Olympic Stadium | McAlpine | Target Cost (NEC3 Option C) | Construction of the 80,000 capacity stadium was completed in March 2011 safely, on time and within budget. |
| Aquatics Centre | Balfour Beatty | Target Cost (NEC3 Option C) | Completed in July 2011, this iconic building housing two swimming pools was designed by architect Zaha Hadid with two temporary "wings" to provide 17,500 capacity during the games and 2,500 capacity in legacy. |
| Velodrome | ISG | Target Cost (NEC3 Option C) | Construction of the cycling track was completed in February 2011. |
| Athletes Village | Lend Lease | Changed from Construction Management (CM) to mix of CM and Design & Build (fixed price NEC3 Option A) | Completed in December 2011 provided accommodation for 17,000 athletes and officials and 2,818 new homes in legacy. |
| International Broadcast Centre & Main Press Centre (IBC/MPC) | Carillion | Design & Build (fixed price NEC Option A) | Completed in July 2011, this venue supported 20,000 broadcasters and journalists during the games. |
| | | **Largely temporary Structures** | |
| Eton Manor | Mansell Construction Services | Managed Packaged Strategy | Aquatics training venue with three Olympic size temporary swimming pools during the Games. Dismantled and transformed to host wheelchair tennis during Paralympics. After the Games turned into multipurpose sports centre. |
| Basketball Arena | CLM | Managed Packaged Strategy | Construction of the 12,000 capacity venue was completed in June 2011. Dismantled after the Games and reused at other UK and overseas events. |
| Water Polo | CLM | Managed Packaged Strategy | 5,000 capacity temporary venue completed in. Components dismantled and reused elsewhere in the UK. |

**Table 2: Major systems within the Olympics Park**

| | |
|---|---|
| | **Organization, capabilities and contracts** |
| ODA | Public sector client organization (250 staff) managers interface with sponsor, defines the scope and budget, and coordinates with delivery partner<br><br>Responsible for managing “upwards” to diverse external stakeholders (international, national and local), single government interface, and minimising “noise” to shield CLM from external interventions<br><br>ODA-CLM co-located during planning to build team and align objectives |
| CLM | Private sector delivery partner (600 staff) manages programme, PCs and communication with ODA<br><br>Combines specialized capabilities and complementary assets of CH2MHill, LOR and Mace<br><br>NEC3 Professional Services contract with ODA to bring “highest skills |
| Principal contractor (PC) | Contractors with capabilities and prior experience in specific systems (e.g. stadia and roof structures)<br><br>Suite of NEC3 contractors with PCs tailored to complexity of each project<br><br>CLM co-located with PCs and ODA representative on site in integrated project teams during construction |

**Table 3: London Olympics 2012: Organizational structure**

| | Organization | Capabilities |
|---|---|---|
| **ODA** | "Building an organization and scratch and delivering the kind of programme we had, there was no way we were going to do it organically, and, so, quite early on, we made a decision that we needed a private sector partner, a really tough, experienced public sector partner that could bring, if you like, existing processes and tools and delivery capability to work alongside us to deliver this".<br><br>"You can't tell who's ODA and CLM, it's fully integrated".<br><br>"We actually needed to have a much more open and collaborative relationship and build that relationship and the trust, so we spend a lot of time together, we have a lot of joint meetings and I think we've established a remarkable level of, sort of, openness, honesty and trust". | "We just knew over time that we needed different skills and probably different bits of a delivery partner and there was, maybe with Bechtel aside, there was probably nothing out there on the shelf that it was, you know, you could point to and say, you know, that's what we want, so we were in, sort of, somewhat new charted territory really".<br><br>"We obviously had three companies coming together in terms of Laing O'Rourke, CH2M Hill and Mace, all with track records…We could buy first of all into three companies, dig in all their resources, we weren't just limited to individuals. Secondly, they could hire quickly, they could tap people on the shoulder, whether in Australia, America or the UK or wherever, get the best people, best fit. We could de-mobilise those people just as quickly, take them back into their businesses or let them go; so they had complete flexibility. So they were able to rapidly mobilise, they were able to flex to meet changing circumstances, expected or unexpected". |
| **CLM** | "Three different companies, three organizations, existing organizations that had to come together in an entity. We had a programme manager, a project manager, and a builder. We had to make that group into a fit for purpose programme and project manager…The fact that we've been able to find a way to operate in an integrated and highly open structure has enabled us organizationally to get a level of confidence and trust with each other. So even though we operate in a very clear hierarchy, we operate within my organization and ODA up, down, and across each other's organization with impunity: a very open structure. So I will have some of my project managers report directly in meetings to ODA directors and ODA sponsors without my senior management or myself present. So we've cultivated that method of working".<br><br>"The interface between the delivery partner and the client is where a lot of the magic happened. They had this, these really high level goals that they set us, and it was in how it got turned into something that happened". | "The make-up of the delivery partner was also something unique because you brought in a contractor, Laing O'Rourke, you brought in a construction manager/project manager MACE and you brought in somebody with international programme experience CH2mHill too. And they blended those together to give, to assure you have the right skills to manage this programme on behalf of the ODA… It's all about understanding the risk and the delivery of the job".<br><br>"A delivery partner, in the main, here, the client doesn't write the instructions; they'll talk to us about a problem, we'll get round the table, and always, in the final analysis, we'll throw around different ideas, and we'll say, okay, let us give something back to you with some ideas, maybe some solutions".<br><br>"The concept of a delivery partner came into being, and that was very much around programme management with real project management and construction delivery expertise. So the ability to have a much broader band width of a partner". |

**Table 4: Organizing meta systems integration: illustrated interview quotations**

| | Meta systems integration | System integration |
|---|---|---|
| **ODA** | "Our job was all around the, sort of, assurance and governance, getting all of those approvals, you know, be they all our planning approvals, all our business case and financial approvals, and, sort of, you know, all of those days of going to Olympic board, getting all of the sign-offs, you know, managing the politicians, managing the stake… so managing all of that stuff that happens around a big project and almost, sort of, creating this cordon around the delivery machine that they were looking down on the site and getting on with it and they weren't being distracted, and they were saying to us, this is when we need all these permissions, this is the critical path, you know" (ODA interview).<br><br>"The ODA has done a first-class job in protecting us from external pressures, and they have contained a lot of the opinions, if you like, that have been brought to bear on the project. So they've acted as an umbrella to us" (CLM interview).<br><br>"ODA are at the top, we sit in the middle, and everything should be more or less coming down, but, of course, relationships go across that" (CLM interview). | "So you get a programme view of life, and you've got a project view of life. And the sponsors being given the freedom to do their job, to have their job clearly defined, but being given the freedom to do it and to manage the stakeholders as they see appropriate. And you've probably met a few of the sponsors and we are individuals and I think we do our job in different ways on many of the projects, But effectively we all operate within the same framework and get the same outputs" (ODA interview).<br><br>"It's, kind of, generic across all of them really, so the project sponsor sets the brief, gets stakeholder buy into the brief, physically gets their sign-off to it. So you've got a good strong baseline document involved in the procurement of the design team. And then subsequently the contractor acts as the point, as the client direction for any change or for controlling change, for accepting the designs against the requirements of the brief, getting stakeholders sign-off at intermediate stages as the design develops, and managing the stakeholder group throughout the project process. And having a project manager of each and individual project report to you formally through a monthly progress meeting on-site, but informally on a day to day basis" (ODA interview). |
| **CLM** | "Internally have a group of people that are focused downwards – absolutely focused on delivery, absolutely making the milestones, absolutely ensuring that the supply chain" (CLM interview).<br><br>"The fact that the contracts were all set up in the first place to make it very clear that these interfaces exist. So you can't ever argue, well, I don't need… I'm just going to do my own thing, I'm not going to interface with anyone else, I just want to delivery my work and walk off. It's… the fact that the contracts were always set up to highlight all these interfaces" (CLM interview).<br><br>"But he's [the PC] just drawing himself on his little island, and you know, on that island it was for him to build it, but who is gluing that with the rest of the park? And it's only through time, I think, some of the contractors thought, aah, you know, so it's CLM who are actually gluing us all together, as well as this role very much of the assurance and overall direction of the whole" (CLM interview). | "So you had to have a good programme from your, from each of your contractors, and then we had to roll that into something that was in, you know, integrated but not so huge and complex that you couldn't see the wood for the trees" (CLM interview).<br><br>"Your role is a more, a higher level project manager, because you're given the interface between the design and the construction to that contractor, they've defined what they're building, they're managing their tier two contractors. Obviously you're monitoring cost and any other peripheral changes that are coming in as different processes rolled in, but basically, that can be ring-fenced and you've only got people crossing the border, you know, for peripheral things, generally speaking" (CLM interview).<br><br>"There never has been any white space on this project…every piece of ground, every square meter of ground is owned by a principal contractor. The actual map of the park looked like a piece of tartan, because it was all split up" (CLM interview). |
| **PC** | "So, we've got so many different interfaces, you know, the red lines on each of the buildings obviously give, you know, there's clear responsibility within that full delivery of whatever that might be… So, as we collapse and wrap up the project that co-ordination internally becomes even more important. But, then, there's the co-ordination outside. We are adjacent to Westfield. We are adjacent to railway lines. We're adjacent to rivers and waterways. We're adjacent to the Olympic Park. There's an awful lot going on there and that co-ordination's absolutely critical" (PC interview). | "There's no day-to-day relationship between the different contractors at all, except where we're touching next, where we might have an infrastructure to put in on their doorstep. So the site has been set up within discreet PC areas so we're working within a boundary within a boundary, as it were. And we're being, as I say, left to get on with our work. I think it's worked very well" (PC interview). |

**Table 5: Levels of systems integration: illustrated interview quotations**

| Baseline planning | Controlled change |
|---|---|
| "We have right from the beginning of 2006 established what we call our milestones, and they were for the different phases of the project. So, you had the dig, demolish, design phase that's pretty much designing the venues, demolishing the buildings, starting digging the foundations. Very public milestones, ten milestones, and publically announced so the public could track, and our stakeholders and the media, could track our progress" (ODA interview).<br><br>"[Blue book] not a document that does a warm up piece on every project, but it puts down, in highlights, exactly what you're building on a project, what the timetable is, what the deliverables are, what the cost's going to be, some sub-division of that cost and all of that" (ODA interview).<br><br>"The Blue Book was like an umbrella for the project under which CLM can get on with their work…It set out the programme and time and people could see very clearly from the outside, if we don't let the procurement at this date, and if we don't finalise the design at that date, we're going to start running late on this project.. There was an integration between the project and how things had to come together on the site; it was very clearly structured within the document" (ODA interview). | "We set up a change board, we set up a process with CLM that meant if you wanted to change the schedule, the milestones, if you wanted to change the scope and that had financial consequence, you had to take a change through a monthly change board… We kept a very tight control check, change was the enemy of the project, we said that from the outset; we wanted to be change resistant" (ODA interview).<br><br>"We decided early on to use the NEC contract, NEC 3, basically because needed to identify risks early on, through the early warning structure, so that you could map out cost and change and schedule implications, you know, almost in a real time situation. Because if went to traditional contracting, you needed lots of fixed price stuff, you just wouldn't get visibility" (CLM interview).<br><br>"The ODA as well, but especially for CLM, I think it's been the flexibility issue, has been the fact that, whether it's organizationally or procedurally or what-have-you, it's having the right amount of discipline but, yet, also having the right amount of flexibility. By flexibility, I mean moving the right people to the right spot at the right time, changing your organization chart…It really has been a good, cooperative team effort" (CLM interview).<br><br>"Here's two elements to change: there's change in terms of client change and understanding client change; we've established a formal change board in governance with the ODA; I think it worked brilliantly. People who were not used to it, project managers, don't like it because of the rigour in the discipline…You know, nearly 2,000 changes to date, full visibility and traceability of decisions. But what we've done is, we've rejected just under 500 changes and decided not to do it; that's saved money, because of this collective visibility" (CLM interview). |

**Table 6: Systems integration: balancing stability and change: illustrated interview quotations**

## Appendix A: List of Interviews

| | Date | Interviewee | Affiliation | Job title / Function |
|---|---|---|---|---|
| | | **Phase 1: Programme level** | | |
| 1 | 17-Nov-10 | Carline Blackman | CLM | Head of Organizational Development |
| 2 | 17-Nov-10 | Louise Hardy | CLM | Infrastructure Director |
| 3 | 24-Nov-10 | Ken Owen | CLM | Commercial Director |
| 4 | 25-Nov-10 | Mark Reynolds | CLM | Deputy Programme Director |
| 5 | 01-Dec-10 | Ian Galloway | CLM | Programme Director |
| 6 | 01-Dec-10 | Simon Wright | ODA | Director of Utilities |
| 7 | 08-Dec-10 | Ken Durbin | CLM | Technical Services Director |
| 8 | 08-Dec-10 | Alison Nimmo | ODA | Director of design and regeneration |
| 9 | 15-Dec-10 | Richard Rook | CLM | Director of Construction Integration |
| 10 | 15-Dec-10 | Hugh Sumner | ODA | Director of Transport |
| 11 | 15-Dec-10 | Michele Owens | ODA | HR Manager |
| 12 | 15-Dec-10 | Howard Shiplee | ODA | Director of Construction |
| 13 | 28-Jan- 11 | Dennis Hone | ODA | Director of Finance; CEO |
| 14 | 02-Feb-11 | Jason Millett | CLM | Venues Director |
| 15 | 09-Feb-11 | John Armitt | ODA | Chairman |
| 16 | 09-Feb-11 | Alice Coates | ODA | Marketing Strategy |
| | | **Phase 2: Project level** | | |
| 17 | 17-Mar-11 | Tony Aikenhead | McAlpine | Stadium - Project Director |
| 18 | 17-Mar-11 | Chris Hall | McAlpine | Stadium - Project Manager |
| 19 | 17-Mar-11 | Richard Rook | CLM | Stadium - Project Manager |
| 20 | 28-Mar-11 | Simon Birchall | CLM | Athletes Village - Project Manager |
| 21 | 28-Mar-11 | Mark Dickenson | Lend Lease | Athletes Village - Project Director |
| 22 | 28-Mar-11 | Alan Bates | ODA | Athletes Village - Project Sponsor |
| 23 | 31-Mar-11 | Dean Goodliffe | ISG | Velodrome - Project Director |
| 24 | 31-Mar-11 | Davendra Dabasia | CLM | Velodrome - Project Manager |
| 25 | 06-Apr-11 | Colin Naish | ODA | IBC/MPC - Project Sponsor |
| 26 | 06-Apr-11 | Tony Coyle | Carillion | IBC/MPC - Project Director |
| 27 | 10-May-11 | Danny Richards | CLM | Basketball - Project Manager |
| 28 | 10-May-11 | Dave Coulson | CLM | Basketball - Project Manager |
| 29 | 10-May-11 | Richard Arnold | ODA | Basketball - Project Sponsor |
| 30 | 22-July-11 | Michael Lytrides | CLM | IBC/MPC - Project Manager |
| 31 | 04-Aug-11 | Ian Crockford | ODA | Aquatics – Project Sponsor |
| 32 | 05-Sept-11 | Stuart Fraser | Balfour Beatty | Aquatics – Project Director |

## Appendix B: The ODA's Six Priority Themes

The ODA identified six 'priority themes' as follows:

1. Health, Safety and Security
2. Design and Accessibility
3. Equality and Inclusion
4. Legacy
5. Employment and Skills
6. Sustainability

The ODA published a strategy for each of these themes and detailed specific objectives and principles which the ODA was committed to achieve in the course of delivering its programme of construction. These objectives were cascaded down through CLM to Tier 1 contractors and beyond. While the targets and principles were non-negotiable, it was up to each contractor to implement them in their own way. What was crucial was that ODA senior management made it clear that these additional targets were as important as the traditional construction targets. As a result, they were taken seriously – and achieved - right across the programme.