COLLABORATIVE RESEARCH

Project management for large, complex projects

AN EXPERT REPORT BY PROFESSOR ANDREW DAVIES

Association for Project Management
February 2019

THE CHARTERED BODY FOR THE PROJECT PROFESSION

Acknowledgements

AUTHOR
Professor Andrew Davies, School of Construction and Project Management,
The Bartlett Faculty of the Built Environment, University College London
a.c.davies@ucl.ac.uk

Thanks to my co-authors, practitioners working on major UK infrastructure projects, and colleagues in the School of Construction and Project Management at The Bartlett Faculty of the Built Environment, University College London, who have helped to shape my thinking about how to improve the set up and delivery of large, complex infrastructure projects.

RESEARCH SPONSOR
Daniel Nicholls, APM

Contents

Introduction

This expert report on project management was commissioned by the Edinburgh Tram Inquiry to address general issues about the nature, purpose and application of project management, as well as specific questions about programme management and risk management.

Traditional project management provides a set of processes, procedures and tools for managing projects on time, within budget and to the required specifications. These common processes are valuable for identifying the bodies of knowledge and detailed procedures required to set up and execute projects.

However, traditional project management has been criticised in recent years for neglecting to consider the 'strategic' activities and decisions undertaken during the front-end planning stage of projects, which play a vital role in defining the need for a project and determining whether the goal is achieved.

Traditional project management assumes that a one-size-fits-all approach – a simple, predictable and standardised model – is applicable to all types of projects. Recent research has emphasised the need for project management to be 'adaptive' and flexible to address the complexities, uncertainties and challenges surrounding each project.

"Many infrastructure projects in the UK now recognise the need for solutions that are designed to deal with the specific challenges involved in planning and executing large, complex projects"

There are clearly no magical project management cures, and no single predictable strategy will be applicable to all large, complex, high-risk projects. But many infrastructure projects in the UK now recognise the need for solutions that are designed to deal with the specific challenges involved in planning and executing large, complex projects.

Taken together, the strategic and adaptive approaches to project management identified in this report offer a more effective way of planning and managing large, complex projects.

Concepts and definitions

What is a project?

A project is a unique, transient endeavour undertaken to achieve planned objectives, which could be defined in terms of outputs, outcomes or benefits. A project is usually deemed to be a success if it achieves the objectives according to their acceptance criteria within an agreed timescale and budget.

"Projects range in size and composition, from small in-house project teams to dedicated temporary organisations and large multi-party structures"

A key factor that distinguishes project management from just 'management' is that it has a final deliverable and a finite time span, unlike management, which is an ongoing process. Because of this, a project professional needs a wide range of skills – often technical skills – and certainly people management skills and good business awareness.

For full definitions and detailed explanations of the concepts and topics involved in project management, please refer to the *APM Body of Knowledge* publication.

Projects and operations

The differences between projects and operational activities are:

Project

- A project produces unique, heavily customised or one-off products and services to address the requirements of individual clients (eg a new generation of aircraft, an urban railway system or an airport).
- Projects are one-time endeavours designed to undertake novel, innovative, problem-solving tasks.
- Projects are a flexible and adaptive way of dealing with individual client requirements and promoting innovation when conditions are complex, fast-changing and uncertain.

Operational activity

- An operational activity produces standardised products and services in high volumes (eg cars, smartphones or fast-food meals).
- Operations perform standardised procedures and repetitive tasks on a continuing basis.
- Organisations peforming projects are designed to prosper and grow when conditions are stable and predictable.

In some cases, projects and operations are bundled together and provided as part of a single contract, such as private finance initiative and public-private partnership contracts. These projects extend from design and construction into the provision of services required to operate the asset over many years or even decades.

Project success

A clearly defined project goal and progress towards achieving that goal are measured by time, cost and quality – the three constraints of project management, or the 'iron triangle'. The job of the project manager is to complete the project on time, within budget and to the required specifications. Trade-offs between the three constraints are often made to achieve the project's goal.

"Although the time available to complete the construction of the London 2012 Olympics infrastructure and venues was fixed, the budget and quality could be manipulated to achieve the goal"

For example, although the time available to complete the construction of the London 2012 Olympics infrastructure and venues was fixed, the budget and quality could be manipulated to achieve the goal. If the schedule is shortened, more resources and a bigger budget may be required to deliver the project in less time.

On the other hand, if the budget is reduced, often the schedule may have to be lengthened. For example, London's Crossrail project was asked to reduce the overall budget by £1bn to achieve the new requirements established in the government's 2010 *Comprehensive Spending Review*. To achieve this revised constraint, the tunnels and stations were constructed sequentially rather than in parallel, and the end date of the project was extended.

How we evaluate success depends on whether we focus on the outputs or outcome of a project. The triple constraints model of project success is a useful measure of short-term outputs. However, trade-offs between the constraints are frequently made without considering the fourth constraint of 'client satisfaction' and other longer-term project outcomes. There is a growing recognition that project success is multidimensional.

Shenhar and Dvir (2007) identify five dimensions of success:

1. Efficiency – achieving budget, time and other efficiencies.
2. Impact on the customer – meeting client requirements and achieving customer satisfaction.
3. Impact on the team – maintaining the morale and developing the skills of team members.
4. Business and direct results for the organisations involved – sales, profits, service quality, etc.
5. Preparation for the future – creating new technology, markets, core competency and capabilities.

The importance of these five dimensions varies over time. Efficiency is a short-term measure of success when the project is completed, whereas preparation for the future can only be assessed many years later. For example, the construction of the venues and infrastructure for the London 2012 Olympics met short-term time, cost and quality goals, but the London 2012 'legacy' objectives for the local economic development of East London have to be evaluated years after the completion of the project.

Conditions for project success

APM has conducted independent research in the area of conditions for project success that seeks to identify the core factors that lead to the successful delivery of projects, programmes and portfolios.

The research identified 12 success factors, known as APM's framework for success. From this, five factors were found to have the strongest and most consistent relationship with the traditional measures of project success: time, cost and quality. Those factors are:

1. Project planning and review.
2. Goals and objectives.
3. Effective governance.
4. Competent project teams.
5. Commitment to success.

To find out more and download the report, click here.

What is project management?

Project management is the application of processes, methods, knowledge, skills and experience to achieve the project objectives.

Project life cycle

All projects have a life cycle with a beginning and definite end date, alongside intervening phases, such as planning, execution and commissioning. The characteristics of each phase and names used to describe the activities involved vary depending on the type of project and the management approach of the parent organisation.

"Ericsson developed an in-house project management process for defining phases and activities required to develop and implement mobile communications systems"

Methodologies developed to support project life cycle activities may be unique to a firm and industry. Ericsson, for example, developed an in-house project management process (called PROPS) for defining phases and activities required to develop and implement mobile communications systems, including pre-study, feasibility study, execution and conclusion.

Large and complex projects require exceptional levels of control, and work is divided into phases tailored to the unique requirements of each project. For example, the London 2012 Olympics was divided into annual phases to provide the visibility and clarity of focus required to achieve the project's time-critical deadline.

All life cycles follow a similar, high-level generic sequence, but this can be expressed in different ways. Life cycles will differ across industries and business sectors. The most common type is the linear life cycle, sometimes known as the linear sequential model or waterfall method. In addition to the linear model, other life cycle formats include:

- Parallel – similar to the linear, but phases are carried out in parallel to increase the pace of delivery.
- Spiral – often employed where many options, requirements and constraints are unknown at the start (eg in prototyping or research projects).
- 'V' – applied in software development where requirements are defined and the development tools are well known.

Phase-based development

There are at least three different processes for managing the relationship between phases in the project life cycle. The main ones are:

1. Sequential process

In a sequential process, a downstream phase (eg construction) starts when an upstream one (eg design) ends. Strict entry and exit criteria have to be satisfied (eg milestones, stage gates, phase exits and decision gates) before the project can transfer to the next phase. Sequential development reduces uncertainty but limits opportunities to explore alternative ways of completing the schedule more rapidly.

2. Overlapping or concurrent process

Here a downstream phase starts before an upstream one is completed. While this approach provides opportunities to compress the time taken to complete the schedule, it may increase uncertainty and the possibility of rework if a downstream phase occurs before accurate information is available from a previous phase.

3. Iterative process

In an iterative process, only one phase is planned at any time, and the planning of the next phase occurs while work on the current phase is ongoing. Iterative development is associated with 'agile methodologies' and is often used for novel, uncertain and fast-changing environments such as research and new product development.

The phased structure facilitates the creation of governance and feedback mechanisms:

- Stages – development work can be further subdivided into a series of management stages (usually referred to as 'tranches' in programmes), with work being authorised one stage at a time.
- Gate reviews – these are conducted at the end of a phase, stage or tranche. Senior management will consider performance to date and plans for the next phase, stage or tranche before deciding whether they are viable.
- Post-reviews – learning from experience is a key factor in maturity. Post-project/programme reviews document lessons learned for use in the future.
- Benefit reviews – these measure the achievement of benefits against the business case.

All phases of the life cycle are important. No phase should be omitted, but they may be adjusted to accommodate the development methodology and context of the work.

Project stakeholders

"There are many organisations involved in a project whose interests may be positively or negatively affected by the performance or outcome of a project"

There are many organisations involved in a project whose interests may be positively or negatively affected by the performance or outcome of a project. While some key stakeholders are involved in projects during a particular phase (eg investors and policymakers in front-end planning), the key actors involved throughout the life cycle of a project include the project sponsor, manager and users.

Project sponsor

This is the person or organisation that owns the project, champions the original idea, obtains financial resources, provides a link to the senior management in the parent organisation, and leads the project until formally sanctioned to proceed to implementation and execution.

Project manager

The project manager is responsible for achieving the project goals and communicating with all of the stakeholders, including the sponsor, the project team and the customer. The project manager and members of single or multi-party teams work in a temporary organisation to implement and execute the project.

Users

The needs of customers and/or users must be articulated and translated into the project's requirements. Users of the product may be internal (eg organisational change programme) or external (eg Transport for London) to the parent organisation.

"BAA was the project sponsor of Heathrow Terminal 5, while British Airways occupied and used the facility as its operational hub, and its passengers were the project's end users"

The distinction between sponsor, customer and user is often blurred. In some projects, customers and users are the same entity, while in others customers own the product of the project and users are those who directly utilise the product of the project. For example, BAA was the project sponsor of Heathrow Terminal 5 (T5) and a major user of the new terminal building. British Airways, T5's main customer, occupied and used the facility as its operational hub, and its passengers were the project's end users.

The project manager

Project managers are responsible for achieving a specified goal and completing the project on time, within budget and to the required specification. They establish a well-defined plan and then manage the plan until the project achieves its goal. They help to identify and address the requirements, expectations and needs of the client and other stakeholders involved during the planning and execution of a project.

Project managers also establish budgets, checkpoints, schedules and time estimates, identifying the risks and resources required to achieve the overall goal. They manage, motivate and empower individual members of a project; build agreements to mobilise teams; and encourage creativity, innovation and problem-solving to address problems or opportunities not anticipated at the start of the project.

When projects are complex, unpredictable and changing, plans have to be flexible and projects adjusted to situations that cannot be foreseen at the start. Changes to the project requirements may create additional uncertainty. The project manager must evaluate the changed conditions and balance cost, time and quality demands in order to deliver a successful project.

Project management and functional management

The role of the project manager is distinct from that of a functional manager. A project manager is assigned to achieve the project's goal, whereas a functional manager is responsible for continuing development and oversight of a particular function, such as engineering, manufacturing or sales.

There are a variety of ways of organising project and functional activities. Performed by in-house or large, multi-party teams and organisations, projects can be located on a spectrum of organisations from functional to pure project structures:

Functional organisation

At one end of the spectrum, a functional organisation is subdivided into departments such as engineering, production, finance and sales. Each employee reports to a functional manager, and each department undertakes project work independently of other departments.

Project organisation

At the other end of the spectrum, a project organisation contains all of the functional resources required to achieve a project goal. Team members are often co-located in a single office or location and report to a project manager. Project organisations often have a great deal of autonomy, control, a clarity of purpose and the independence required to focus on achieving a single goal.

Matrix organisation

In between these two extremes, a matrix organisation combines functional and project structures. Members of a matrix organisation have 'two bosses', reporting to a functional manager as well as a project manager. There are many different types of matrix organisation. Some are described as weak when the project manager has limited control, while others are strong if the project manager has considerable authority over resources, staff and funding.

Project contracts

A contract is a mutually binding legal document or agreement between a sponsor and a contractor, subject to resolution in the courts. Under the contract, the sponsor is obligated to provide payment for the product or services provided and the contractor is obligated to provide the specified products, services or outcomes. A contract is a mechanism for allocating responsibility for managing risks, such as sharing the risks or transferring them to the supplier. There are three main types of contract: fixed-price, cost-reimbursable, and time and material contracts (PMI, 2013):

Fixed-price contracts

Fixed-price contracts establish a fixed budget for the provision of a product, service or outcome. Suppliers are obligated to complete fixed-price contracts within budget or incur financial damages if they fail to do so. Changes in scope involve some increase in the contract price.

Cost-reimbursable contracts

Cost-reimbursable or cost-plus contracts involve payments to the seller for all actual costs incurred for the complete work, with a ring-fenced profit. These contracts may include financial incentive clauses when a seller exceeds or falls below defined performance targets for cost, time or quality. A cost-reimbursable contract provides the flexibility required to address scope changes or unforeseen events that were not defined at the start and need to be adjusted while the project is under way.

Time and material contracts

Time and material or professional services contracts involve a mix of fixed-price and cost-reimbursable arrangements and are used to increase staff numbers and acquire external expertise or other resources when a precise statement of the scope of work cannot be established at the start. The full cost of this type of contract may not be defined or known by the buyer at the time of contract award.

Project risk and opportunity management

"When an uncertain event occurs, it may have an impact on one or more project objectives, including scope schedule, cost and quality"

Risk management is used to identify the risks and uncertainties that might impact on a project in the future. When an uncertain event occurs, it may have an impact on one or more project objectives, including scope schedule, cost and quality. Uncertainties may stem from one or more causes and have one or more impacts on the project. The cause of the event or condition can have positive or negative outcomes. There are two types of uncertainty: foreseen (risk) and unforeseen, defined as:

Foreseen uncertainty

A foreseen uncertainty or 'known unknown' is an event or condition that can be identified and analysed in advance. Plans can be prepared to address those risks should they occur during the project.

Unforeseen uncertainty

An unforeseen uncertainty or 'unknown unknown' is an event or condition that cannot be identified or analysed in advance. A contingency plan should be established to address unforeseen uncertainties, should they arise during the project.

Strategies for managing risk include:

1. Changing the project management plan to avoid the risk entirely.
2. Transferring or sharing the risk with a contractor.
3. Taking early action to mitigate the risk.
4. Accepting the risk without adjusting the plan.

Strategies for dealing with opportunities (positive risks) include:

1. Exploiting an opportunity.
2. Sharing the opportunity with a third party.
3. Enhancing the positive impacts and encouraging their occurrence.
4. Accepting an opportunity when it happens without actively pursuing it.

Participants in a project, including the project manager, team members, customers, end users, consultants and other stakeholders, may be asked to establish a risk register. This involves identifying risks that may affect a project, documenting their characteristics and rating the probability of their occurrence (scored low to high).

Various qualitative and quantitative information-gathering techniques are used to identify risks such as expert judgement, brainstorming, interviewing, knowledge of other comparable projects, historical data, modelling and simulation, and so on. A 'risk register' includes a list of identified risks and potential contingent responses for dealing with them should they occur, and compares the impact of one risk against others in a project.

Risk identification is an ongoing process as new risks and uncertainties may manifest as the project progresses towards completion. An 'opportunity register' includes a list of potential opportunities (eg new practices, tools, materials and technologies) that may be applied to complete the project more efficiently and effectively.

Projects, programmes and portfolios

In many organisations, project management is undertaken in a wider context of ongoing programmes and portfolios. A project can form part of a continuing programme of interrelated projects using shared resources and capabilities to achieve a common objective, such as the nationwide rollout of a mobile communication system.

Programme management is the coordinated management of projects and change management activities to achieve beneficial change. Projects and programmes can form part of a portfolio that is planned, mapped and sequenced to achieve an organisation's long-term strategic objectives. A number of interrelated projects or programmes are grouped together to improve overall coordination and management of an organisation's mix of projects.

"All projects, programmes and portfolios are designed to deliver objectives, which may be expressed as outputs, outcomes or benefits"

A project life cycle defines the interrelated phases of a project, programme or portfolio and provides a structure for governing the progression of the work. All projects, programmes and portfolios are designed to deliver objectives, which may be expressed as outputs, outcomes or benefits. A project, programme or portfolio life cycle illustrates the distinct phases that take an initial idea, develop it into detailed objectives and then deliver those objectives.

Evolution of the discipline

This section discusses the origins and foundations of project management as a discipline and identifies recent attempts to rethink how we understand and apply project management in today's increasingly complex, uncertain and fast-changing world.

Traditional project management: origins and foundations

"The Manhattan Project, which developed the atomic bomb during the second world war, is often credited with laying the foundations of modern project management"

Project management emerged as a formal discipline at the end of the 1960s. The Manhattan Project, which developed the atomic bomb during the second world war, is often credited with laying the foundations of modern project management. However, the core structures, processes, tools and techniques of project management were pioneered by people and organisations involved in the United States' large weapons, defence and space systems projects after the second world war (Morris, 1994 & 2013).

Many innovative ideas were generated to manage the development of the Atlas intercontinental ballistic missile (ICBM) project in the late 1950s. Working alongside the new discipline of systems engineering, project management was established as a process for coordinating, scheduling and controlling the design and integration of complex systems comprising numerous interacting components and subsystems incorporating new technology. The 'systems approach' to project management, created to develop ICBMs, was improved further to manage the Apollo moon landing programme during the 1960s and early 1970s (Davies, 2017).

At the end of the 1960s, several professional bodies were established in the United States and Europe to develop standardised procedures, tools and processes for managing projects, including the International Project Management Association in 1967, the Project Management Institute in 1969 and APM in 1972. These bodies aimed to establish project management as a profession comparable in status with others such as law, architecture, medicine and accounting.

APM, the chartered body for the project profession, is committed to developing and promoting project and programme management through its FIVE Dimensions of Professionalism. In 2017, APM was awarded a Royal Charter as part of its strategy to raise awareness and standards in the profession. The receipt of a Royal Charter marks a significant achievement in the evolution of project management. The award-winning association has over 27,000 individual members and 500 organisations participating in its corporate partnership programme, making it the largest professional body of its kind in Europe.

In the *APM Body of Knowledge*, the association offers this definition of project management: "Project management is the application of processes, methods, knowledge, skills and experience to achieve the project objectives."

Traditional project management assumes that once a project plan has been established, the task of a project manager is to execute the project as originally planned – the 'management-as-planned' philosophy. A project starts with a plan based on a scope statement, which includes the work breakdown structure, defining the packages of work, the organisational breakdown structure, network schedule diagrams, the budget and resources.

A baseline plan determines how the project will be executed in some detail and provides a fixed target against which the performance of the project will be evaluated. A risk management plan assumes that the uncertainties facing the project can be identified up front and establishes a contingency plan for dealing with them in the event of them happening.

Once the project is under way, performance is measured against the baseline plan. Ideally, changes should be kept to a minimum or seen as an exception that needs to be corrected. Execution should conform to the baseline plan, even though key assumptions in the plan may be rendered invalid when conditions change.

Rethinking project management: new schools of thought

"While there are many different approaches and underlying theoretical perspectives, it is possible to group researchers and scholars into two main schools of thought"

Over the past decade, a variety of scholars and researchers have challenged some of the assumptions underpinning traditional project management and encouraged us to rethink and reinvent it. While there are many different approaches and underlying theoretical perspectives, it is possible to group researchers and scholars into two main schools of thought: strategic management of projects and adaptive project management.

Strategic management of projects

The first school argues that successful project management depends on strategic decisions undertaken to shape the project during what Peter Morris (1994, 2013) calls the 'front end'. This research emphasises that traditional project management is preoccupied with downstream execution processes and neglects the importance of highly strategic upstream activities and processes, including the need for the sponsor of the project to spend time at the start defining the goals, understanding the benefits and risks, and shaping the strategic approach used to manage and procure the project.

Defining the goal of the project should involve a dialogue between the sponsor, project manager and end user to clarify what they want and how they may benefit from the project. Many sponsors are finding that bids specifying the operational outcome, rather than detailed technical specifications, for the performance of a hospital, railway or IT system create better and more innovative outcomes.

The sponsor has to engage with multiple stakeholders (eg politicians, users, contractors, local businesses and other stakeholders) whose interests, expectations and concerns may be affected positively or negatively by the performance and outcome of the project. The risk of misalignment, cultural differences and conflicts among stakeholders is particularly acute when projects are situated in urban or semi-urban areas and tend to have considerable social, environmental and distributive impacts.

In their efforts to obtain funding and approval, sponsors often underestimate the costs, risks and completion times, overstating the benefits of their favoured project. Bent Flyvbjerg (2014, 2017) has shown that the tendency to underestimate the out-turn costs, or 'optimism bias', can be avoided in the front end by systematic efforts to study and learn from comparable projects undertaken in the past. In some cases, the final cost may be deliberately underestimated (a process called 'strategic misrepresentation') to gain approval for funding.

Strategic thinking about projects has also identified the challenges involved in the execution of a project and 'back-end' transition or handover from the project to operations when outputs (eg a new fleet of trams) are handed over and translated into operational outcomes (eg a functioning tram system).

Adaptive project management

The second school of thought challenges the one-size-fits-all assumption of traditional project management that all projects can be managed in a similar way. Projects are shaped by the conditions of the environment in which they are planned and executed, and vary considerably in terms of their complexity, uncertainty, urgency, novelty, size and other dimensions.

"While a few projects are predictable, stable and unchanging, in most cases plans have to be realistic to deal with future conditions that cannot be fully comprehended at the start"

While a few projects are predictable, stable and unchanging, in most cases plans have to be realistic to deal with future conditions that cannot be fully comprehended at the start, and adaptive and responsive to unexpected conditions, problems and opportunities encountered when the project is under way.

Much of this work has focused on distinguishing between projects according to a particular dimension, such as the degree of novelty, complexity or uncertainty, and creating the right management approach to address it. Over the past decade, for example, research suggests that traditional techniques for managing risk may work well when conditions are familiar and well understood, but efforts to 'get back to the plan' often fail when a project faces unexpected situations or rapidly changing conditions. When too many unknown conditions exist to allow accurate forecasts, project plans, instructions and phased-based execution, activities have to be adjusted as new information becomes available about the project and its environment.

The agile methodology is a recent example of adaptive project management. It was developed to offer an alternative to the traditional phased-based approach and its emphasis on an early design freeze, fixed scope, sequential phases of rigid front-end planning and execution, and limited customer interaction. Agile is an iterative and incremental 'rolling wave' process designed to facilitate flexibility, adaptation and responsiveness to novel, innovative and fast-changing technological and market conditions. Ray Levitt (2011) suggests that the move from traditional to adaptive and agile project management entails a shift to 'project management 2.0'.

Others distinguish between project organisations based on the degree of complexity of the product or outcome produced by a project. Increasing levels of complexity in terms of the number of interconnected components, subsystems and entire systems produced by a project require more elaborate, large-scale forms of organisation to cope with the challenge of integrating multiple components and subsystems, and dealing with interdependencies between sub-projects.

Often problems arise when the organisational structure is unable to cope with the project's level of complexity. In *Reinventing Project Management* (2007), Shenhar and Dvir provide a comprehensive framework – the 'diamond model' – to help managers establish the right organisation and process to deal with the dimensions (complexity, uncertainty, novelty and pace) affecting each project. Table 1 summarises the key differences between traditional and adaptive models of project management.

Approach	Traditional project management	Adaptive project management
Project goal	Getting the job done on time, on budget and within requirements	Getting business results, meeting multiple criteria
Project plan	A collection of activities that are executed as planned to meet the triple constraint	An organisation and a process to achieve the expected goals and business results
Planning	Plan once at project execution	Plan at the outset and replan when needed
Managerial approach	Rigid, focused on initial plan	Flexible, changing, adaptive
Project work	Predictable, certain, linear, simple	Unpredictable, uncertain, nonlinear, complex
Environment effect	Minimal, detached after the project is launched	Affects the project throughout its execution
Project control	Identify deviations from plan, and put things back on track	Identify changes in the environment and adjust plans accordingly
Distinction	All projects are the same	Projects differ
Management style	One size fits all	Adaptive approach; one size does *not* fit all

Table 1: From traditional to adaptive project management (Shenhar and Dvir, 2007: 11)

Strategic and adaptive project management

The strategic and adaptive schools provide a complementary way of thinking about project management and are particularly useful when used to identify the project-specific solutions required to successfully plan, deliver and hand over large, complex and uncertain projects.

Informed by new thinking about project management, this section identifies some of the strategic and adaptive structures, processes and practices required during the planning and execution phases in the project life cycle.

Planning phase

The planning phase is where the project owner – a team including the sponsor, project champion and owner's project manager – plays a vital role in preparing and defining the project goal and objectives. The strategic management of projects literature – including Morris (1994 & 2013), Miller and Lessard (2000), Merrow (2011), and others – argues that it is cheaper and more effective spending money up front on planning, exploring options, obtaining finance, evaluating the risks and designing the project organisation and governance before substantial resources have been committed.

The overall design is more likely to achieve the owner's objectives when all of the key actors from design, finance, construction and operations are involved in specifying and defining project requirements in the early phase. What happens in the front end is vital to the success of a project.

"The way one starts largely determines how one will continue. Get it wrong here and it is likely that the project will go wrong: conversely, spend time getting it as right as possible and it is likely that the project will have a chance of going right" (Morris, 1994).

"The way one starts largely determines how one will continue. Get it wrong here and it is likely that the project will go wrong" (Morris, 1994)

Governance and organisational design

Project governance is a vague and often poorly defined concept that has emerged relatively recently to define the roles and responsibilities, ownership, accountability and structure of the sponsor and contractors involved in a project. As the budget holder and owner of the project, the sponsor is responsible for defining the project's goal and ensuring that the project benefits are successfully delivered. The sponsor plays a vital role in the front-end phase, shaping the governance structure, organisational design, approach to risk management and management of internal and external stakeholders impacted by a project.

The recent history of UK infrastructure projects suggests that the governance of a project depends crucially on whether the client is established as a permanent or temporary organisation. Permanent clients under various forms of public and private ownership (eg BP, Shell, Network Rail, Heathrow Airport and Transport for London) undertake multiple projects on an ongoing basis. They have an opportunity and an incentive to develop the capability internally required to manage a series of large, complex projects and programmes.

Temporary clients, by contrast, are established as a separate company to execute a single large, complex project and dissolve when the task is accomplished. Under government ownership (eg the London 2012 Olympics and Crossrail) or some form of public-private partnership (eg M25 Connect Plus), temporary clients are less able to rely on their parent organisations for project management capabilities and have no opportunity to develop and reuse capabilities on future projects. They depend on prime contractors or joint-venture delivery partners comprised of various contractors to manage the project.

Crossrail, the £14.8bn urban railway system traversing London, is considered a template for the governance of other large, complex government-funded projects. As illustrated in Figure 1, Transport for London (TfL) and the Department for Transport (DfT) – the joint sponsors of Crossrail – established a governing body, the Joint Sponsor Board (JSB). The requirements of the sponsors were defined in the Project Development Agreement (PDA).

While the JSB provides an executive function, the Joint Sponsor Team (JST) is responsible for the day-to-day management of Crossrail Limited. Unlike the Olympic Delivery Authority (ODA), Crossrail Limited was established as a separate company and special-purpose vehicle, so that the risks associated with this endeavour would pose less of a threat to the financial viability of the sponsors should the project start to go heavily over budget.

Crossrail is responsible for reconciling the interests of industry partners (eg Network Rail, London Underground, Berkeley Homes and Heathrow Airport) and wider stakeholders through various forms and non-contractual boards as the project moves through phases from construction to operations.

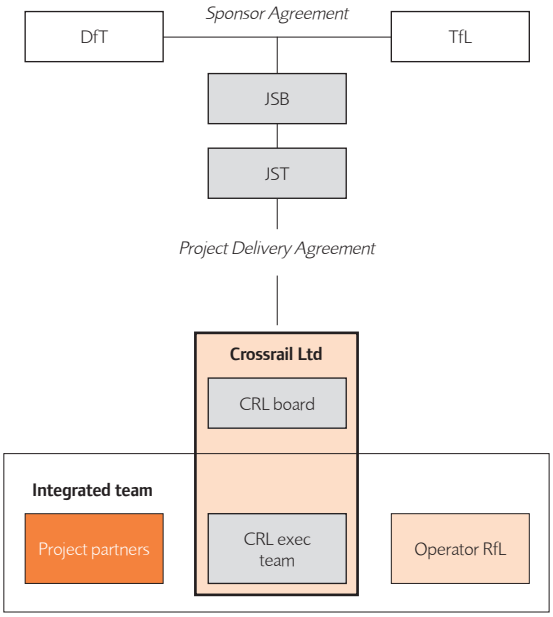

Figure 1: Crossrail structure and governance (adapted from Croft et al, 2016)

An integrated programme team was established that comprised the client delivery body (Crossrail Limited) and two delivery partners: a programme partner (Transcend) comprising CH2M, AECOM and Nichols; and a project delivery partner (Crossrail Central) comprising Bechtel, Halcrow and Systa.

The operator, Rail for London (RfL), has played an increasingly important role in the integrated programme delivery team as the project moves towards completion and handover to operations. As a standalone organisation, Crossrail has the independence, autonomy, clarity of purpose and focus to ensure that the project is delivered and meets the sponsor requirements as defined in the PDA.

"In many cases, the success of the final outcome of a project is enhanced when operators and contractors are involved in front-end decisions about the design and construction of the product or system"

Whether permanent or temporary, clients must decide how early they should engage with contractors and operators. In many cases, the success of the final outcome of a project is enhanced when operators and contractors are involved in front-end decisions about the design and construction of the product or system.

To avoid the risk of an exclusively construction-oriented focus, Crossrail has embedded a small operator group (TfL) in the integrated team. However, the need for an 'operator mindset' should have been more explicitly stated in the PDA, with clearer timescales for the handover to operations (Croft et al, 2016: 19).

Estimating cost, schedule and benefits

In their efforts to gain approval and secure funding, sponsors must estimate the costs, completion times, risks and benefits of the project. In their extensive studies of 'megaprojects' – defined as high-risk projects valued at $1bn or more – Flyvbjerg and his co-authors (2014 & 2017) have found that sponsors are overly optimistic about projects, tending to underestimate the costs and overstate the benefits. In some cases, sponsors deliberately overstate the benefits and/or underestimate the costs to gain approval and make the project more attractive to potential investors.

"Studies have found that most megaprojects are late, over budget and fail to achieve their original objectives. As many as nine out of 10 megaprojects overrun by up to 50 per cent"

Studies have found that most megaprojects are late, over budget and fail to achieve their original objectives. As many as nine out of 10 megaprojects overrun by up to 50 per cent. In seeking to understand the risks involved, managers inclined to rely on their own experience, intuition and skills (the 'inside view') often fail to appreciate all of the possible conditions or the sequence of events that might delay or disrupt the project.

Such optimism bias can be avoided in the front-end planning phase by systematic efforts to learn from other comparable projects using a technique called reference class forecasting to gain a more accurate understanding of a project's probable outcome. Adopting this 'outside view' is supported by recruiting managers and consultants to provide comparative knowledge and statistical data on other projects.

Baseline documents are used to estimate costs, schedules and the risks involved before the project moves to execution. In preparing for the construction for the London 2012 Olympics, for example, the ODA recognised that, although the construction schedule could not be manipulated, a realistic budget and secure contingency were required to cope with the risks and uncertainties surrounding the project. However, the original budget of £4.2bn submitted with the bid document in 2005 severely underestimated the costs of constructing and hosting the games.

The ODA strategic planning team spent a considerable amount of time establishing a baseline definition of the detailed scope, budget, schedule, risk and programme interfaces. This 500-page document, known as the Yellow Book, was published in November 2007. This document had to be revised in November 2009 to become the Blue Book in order to accommodate the new market conditions after the economic downturn of 2008 and numerous changes in scope that occurred since the original publication.

Procurement, contractual approach and risk

The sponsor and client organisation are responsible for establishing the procurement strategy, the contractual approach and the process used to manage risk. Procurement is a common process applicable to all projects. The sponsor or client defines the contract type it intends to use, issues an invitation to tender, receives proposals from various firms, evaluates the bids, and selects the preferred contractor based on criteria used to evaluate the bids (eg cost and quality) and its capabilities, experience and track record. However, there are a variety of contractual approaches that the sponsor/client can rely on to achieve the goals and manage the risks and opportunities surrounding a project.

Project planners often face a dilemma between whether to use fixed-price or cost-plus contracts (Shenhar and Dvir, 2007: 93-94). Fixed-price contracts transfer liability for risks to a contractor or

subcontractor. They focus attention on the start of a project, when specifications are defined and the contract for a definite quantity of money is agreed on, and the conclusion, when the output is accepted or rejected.

"Fixed-price contracts work well when technological conditions are well understood and the design can be frozen at an early stage"

Projects incorporating significant amounts of new technology – both in the process and product – are frequently associated with overruns in cost and time, and risk not achieving planned performance objectives. Fixed-price contracts work well when technological conditions are well understood and the design can be frozen at an early stage, but work less well for novel and technologically uncertain projects because they ignore the need for adaptation to unforeseen conditions while projects are under way. The client receives a less optimal product when the contractor tries to keep within the original budget, and the contractor loses money because of the unanticipated problems.

When conditions are rapidly changing, novel or uncertain, the interests of the client and contractor may be better served by using a cost-plus incentive contract and sharing the risks and opportunities. The contractor has an incentive to improve performance, avoid making short cuts and still make a profit, and the client is willing to bear or share costs in return for receiving a better outcome.

Two UK infrastructure projects undertaken in the 1990s illustrate the problems that may occur when using fixed-price contracts for systems projects incorporating new and uncertain technology. First, National Air Traffic Services (NATS) Limited was the project sponsor of the £623m Air Traffic Control Centre in Swanwick, Hampshire. NATS appointed Lockheed Martin as the prime contractor under a fixed-price contract to assume responsibility for the risks involved in creating the new system.

The technology chosen by NATS was "the most advanced in the world" (House of Commons, 1998). When the project was conceived, it was understood that similar technology would be introduced for the first time in the United States, allowing time to test, prove and resolve any technical problems before it was introduced in the UK. However, the American air traffic control system ran into difficulties and was eventually abandoned.

Although the UK subsequently became the first project to introduce the new technology, NATS decided not to renegotiate Lockheed Martin's fixed-price contract. As a result, the cost of resolving technical and other systems integration problems lay with the contractor. When the centre opened in January 2002, it was more than 100 per cent over budget and six years late.

Second, the Jubilee Line Extension project, part of the London Underground, was also a fixed-price contract. It was designed to incorporate the most advanced radio-based, moving-block signalling system technology. It was scheduled for completion in March 1997 at a cost of £2.1bn.

Construction of the extension started in December 1993, but difficulties with signalling forced the project to abandon the new technology, causing delays and increasing the overall cost. Contractors submitted low-cost bids on the expectation that they could recoup the money and earn additional profits for changes to the specification and unexpected problems encountered during construction. The project was delayed and eventually cost £3.5bn.

In some large, complex projects, a combination of the two contractual approaches may be preferable to target different pieces of uncertainty (eg fixed-price for routine and predictable sub-projects, and cost-plus for uncertain ones) or address the requirements of different phases in the project life cycle (eg cost-plus at the start and fixed-price at a later phase when the uncertainty reduces).

Execution phase

This section focuses on the organisation and management of large, complex UK infrastructure projects and how they adapt, respond and deal with uncertain and changing conditions.

Organising large, complex projects

The literature on adaptive project management identifies two main types of large, complex project (system and array) and suggests that each requires its own distinctive form of organisation, capabilities and formality of processes.

- A system project consists of multiple components and subsystems, often part of a platform, with multiple functions working in combination to address a specific requirement, such as air traffic control systems, buildings and trams.
- An array or 'system of systems' project comprises a large collection of systems, each serving its own specific purpose, that work together to achieve a common goal, such as a city subway infrastructure, an airport or urban development.

System projects produce complex, intangible products and systems, and often provide services through the entire life cycle of the system for training, testing, maintenance, spare parts and operations. System projects are usually managed by a main or prime contractor responsible for systems integration and meeting time, cost and quality goals.

Work is often coordinated by a central project or programme management office to coordinate the technical efforts of in-house functional departments and external suppliers through separate contracts. A degree of formality is required to deal with the technical challenge of defining, designing and integrating a system, as well as various administrative issues, such as reports documenting the work accomplished in terms of financial measures (an earned value report).

The prime contractor requires strong 'systems integration' capabilities to design and integrate all of the component parts into a total system. Since many components and subsystems are outsourced, a systems integrator has to know more about the overall system than any of the individual subcontractors.

Considerable time must be allocated up front for systems integration. Even when each subsystem and component achieves its own specification, they rarely work well together when first integrated as a system. Various interface problems have to be addressed to avoid further delays and cost overruns. Effective configuration management is required to control every design change made and its impact on other components and subsystems.

"The earlier the customer or operator is involved in shaping the final outcome, the more likely the system will achieve its goals"

System projects are particularly difficult to manage and are often associated with poor performance because managers are unable to foresee the final system, understand the risks involved or identify user needs and translate those needs into system requirements. Such projects require a significant degree of customer involvement to identify how the user will operate the system. The earlier the customer or operator is involved in shaping the final outcome, the more likely the system will achieve its goals. But the final systems produced frequently fail to achieve the expected benefits, and support, training and serviceability levels are often lower than originally promised. It is also difficult to define appropriate operational performance metrics for the system in use.

Array projects are often organised as programmes with an umbrella organisation established as a separate entity to formally coordinate and schedule a large number of system sub-projects and deal with the financial, legal and political issues. The client or programme management organisation is responsible for administrating multiple contracts, each devoted to an individual system within the array.

Due to the extent of contracting and the dispersed nature of the project, array projects have to be managed in a very formal way. A great deal of emphasis is placed on the legal and administrative aspects of managing multiple contracts in the programme, while technical challenges are left to managers of the individual system projects who must develop their own procedures for coordination and control. Traditional project management tools (eg a work breakdown structure, a PERT chart or a Gantt chart) are used, but array projects often develop bespoke managerial approaches and project software for planning, controlling, reporting and configuration management.

Contracts, collaboration and innovation

Complexity often increases with project scale, and complexity can give rise to uncertainty. As well as organising to cope with the scale and complexity of projects, dealing with uncertainty and changing conditions is a persistent challenge during the execution of a complex project.

Although efforts are made to minimise uncertainty by identifying risks at the outset, it is not possible to foresee all the eventualities, opportunities and changes in technologies, markets, politics, natural events and other conditions that may occur during the execution of the project. One way of managing uncertainty is to use flexible contracts, work collaboratively and innovate during the execution of a project.

By the early 2000s, UK infrastructure clients began to recognise the limitations of fixed-price contracts that transferred the risks for executing the project to the prime contractor. Swanwick and the Jubilee Line were on a long list of major projects – including the Channel Tunnel, the Scottish Houses of Parliament, the Millennium Dome and Wembley Stadium – that were overdue and over budget.

Building on elements from previous projects (eg High Speed 1), the T5 project has influenced the way in which subsequent projects have been organised, such as the London 2012 Olympics and Crossrail. Many large, complex infrastructure projects are based on collaborative relationships between clients and contractors, and a flexible and innovative delivery model for dealing with uncertainty and change when a project is under way.

"Innovation is important in addressing the varying degrees of uncertainty that can be found within different parts of a large, complex project"

Innovation is important in addressing the varying degrees of uncertainty that can be found within different parts of a large, complex project (Davies et al, 2017). As some large, complex projects contain both predictable and unpredictable elements, a balance has to be found between performing orderly routines when conditions are stable, and adaptation, improvisation and innovative action when conditions change unexpectedly.

A strategy of 'targeted flexibility' can be used to break down complex projects to address the different degrees of uncertainty found in distinct sub-projects (Lenfle and Loch, 2010). A fixed-price contract may be appropriate for sub-projects where conditions facing a sub-project are known and predictable, whereas cost-plus incentive contracts may be required for more challenging and uncertain sub-projects.

The London 2012 construction programme, for example, employed a variety of New Engineering Contracts to target the uncertainty associated with different venues and infrastructure. Collaborative cost-plus, risk-sharing contracts were used to deal with uncertain sub-projects (eg the distinctive Zaha Hadid designed Aquatics Centre), whereas fixed-price contracts were used for predictable and routine sub-projects, such as temporary venues comprising standardised and reusable components.

Innovation programmes

While complex projects depend on flexible cost-plus contracts and collaboration to innovate and adapt to changing and unpredictable conditions, several of the UK's large infrastructure projects have developed a systematic and formal process to harness innovation to complete projects more efficiently and effectively.

In 2013, Crossrail established an innovation programme encouraging contractors, suppliers and other stakeholders to develop, implement and share new ideas, technologies and practices (Davies et al, 2014). An in-house team managed the innovation programme and established a database called Innovate18 to capture all the innovative ideas, proposals and solutions submitted by members of the Crossrail project.

Subsequent large UK projects, including the Thames Tideway Tunnel (TTT), High Speed 2 and the Hinkley Point C nuclear reactor, have established innovation programmes. In October 2016, the Crossrail and TTT projects formed the Infrastructure Industry Innovation Platform (i3P) to share new ideas, practices and technologies with other government-funded projects in the UK.

Systems integration, change control and interface management

All types of complex project – systems and arrays – depend on a systems integrator to coordinate the large network of contracting parties involved in the design, construction, integration, testing, commission and handover of a fully operational facility.

The systems integrator manages the interfaces between sub-projects, deals with system suppliers through separate contracts, and is accountable for meeting time, cost, quality and performance objectives. It relies on formal contracts, shared collaborative goals, change control, configuration management and other forms of persuasion to encourage parties to identify and solve unexpected problems that may arise when components and systems are joined together.

The systems integration may be undertaken in-house by a client body (eg BAA for T5), externally by a prime contractor, or via a collaboration between the client and its delivery partner (eg the ODA and CLM on London 2012).

Handover and transition to operations

"Many complex projects fail because of unsuccessful transitions"

As a project moves to completion, components and subsystems have to be integrated and tested, and end users have to learn how to operate the outputs (hardware, software and services) before the project becomes operational. Many complex projects fail because of unsuccessful transitions (Zerjav et al, 2014).

Take, for example, the chaotic opening of T5 in March 2008 when many flights were cancelled and baggage was delayed and misplaced over a period of 12 days. This disruption happened despite careful efforts by Heathrow Airport to learn from other airport openings and prepare for a successful handover.

Learning from this misguided attempt to open the new terminal in one go, the airport operator decided to prepare for the 'soft opening' of the new Terminal 2 building. A dedicated 'operational readiness' team was embedded in the project organisation two years prior to the official opening on 4 June 2014.

A successful handover was achieved by opening the terminal in stages, including 180 trials with 14,000 volunteers, 1,700 training sessions, a digital 'mock-up terminal' to assess check-in software, a test with a live flight, and a staged process to move each airline into the live terminal building.

Conclusion

This report suggests that traditional project management identifies some of the common processes that should be applied to manage any type of project. In recent years, however, project management scholars and researchers have recognised some of the limitations of the simple, predictable and standardised model of project management:

- Strategic management of projects research emphasises the need to manage the strategic front end of projects, arguing that project success depends crucially on efforts to define the requirements, governance and organisational structure; evaluate the risks; estimate the costs and schedule; manage stakeholders; and design a delivery strategy to achieve the project goals.
- Adaptive project management research argues that there is no magical one-size-fits-all solution – the approach used must address the specific challenges facing each project. The need for project solutions tailored to the uncertainty, complexity and rate of change is even more important for large, complex infrastructure projects situated in urban areas, with many stakeholders often having conflicting objectives, needs and priorities.

"Over the past decade, many of the UK's largest and most complex infrastructure projects have abandoned traditional delivery models"

Over the past decade, many of the UK's largest and most complex infrastructure projects, such as T5, London 2012 and Crossrail, have abandoned traditional delivery models based on a single predictable strategy involving fixed-price contracts that transfer the risk and create adversarial relationships between clients and contractors.

Sponsors responsible for these projects have designed governance structures to manage stakeholders and delivery partners, using flexible contracts and forged collaborative relationships to achieve the innovation and flexibility required to deal with the unexpected risks and opportunities encountered during the planning and execution phases of large, complex and high-risk projects.

References

- J. Armitt. The Armitt Review: An independent review of long term infrastructure planning commissioned for Labour's Policy Review. London: The Labour Party, 2013.
- Association for Project Management. APM Body of Knowledge 6th Edition. Princes Risborough: Association for Project Management, 2012.
- C. Croft, M. Buck and S. Adams. Lessons learned from structuring and governance arrangements: Perspectives at the construction stage of Crossrail. London: Crossrail Learning Legacy, 2016.
- A. Davies. Projects: A very short introduction. Oxford: Oxford University Press, 2017.
- A. Davies and M. Hobday. The Business of Projects: Managing innovation in complex products and systems. Cambridge: Cambridge University Press, 2005.
- A. Davies and I. Mackenzie. Project complexity and systems integration: Constructing the London 2012 Olympic and Paralympic Games. International Journal of Project Management, 32:5 (2014), 773–790.
- A. Davies, D. M. Gann and T. Douglas. Innovation in megaprojects: systems integration at London Heathrow Terminal 5. California Management Review, 51:2 (2009), 101–125.
- A. Davies, S. MacAulay, T. DeBarro and M. Thurston. Making innovation happen in a megaproject: London's Crossrail suburban railway system. Project Management Journal, 45:6 (2014), 25–37.
- A. Davies, M. Dodgson, D. Gann and S. MacAulay. Five rules for managing large, complex projects. MIT Sloan Management Review, 59:1 (2017), 73-78.
- B. Flyvbjerg. What you should know about megaprojects and why: An overview. Project Management Journal, 45:2 (2014), 6–19.
- B. Flyvbjerg, N. Bruzelius, and W. Rothengatter. Megaprojects and Risk: An anatomy of ambition. Cambridge: Cambridge University Press, 2003.
- B. Flyvbjerg (ed). The Oxford Handbook of Megaproject Management. Oxford: Oxford University Press, 2017.

- S. Lenfle and C. Loch. Lost roots: How project management came to emphasize control over flexibility and novelty. Californian Management Review, 53:1 (2010), 32–55.
- R. E. Levitt. Towards project management 2.0. The Engineering Project Organization Journal, September 2011, 197–210.
- C. Loch, A. De Meyer, and M. T. Pich. Managing the Unknown: A new approach to managing high uncertainty and risk in projects. Hoboken, NJ: John Wiley & Sons, 2006.
- E. W. Merrow. Industrial Megaprojects: Concepts, strategies and practices for success. Hoboken, NJ: John Wiley & Sons, 2011.
- R. Miller and D. R. Lessard. The Strategic Management of Large Engineering Projects: Shaping institutions, risks and governance. Cambridge, MA: The MIT Press, 2000.
- M. Morgan, R. E. Levitt and W. Malek. Executing your strategy: How to break it down and get it done. Boston: Harvard Business School Press, 2007.
- P. W. G. Morris and G. H. Hough. The Anatomy of Major Projects. Chichester: John Wiley & Sons, 1987.
- P. W. G. Morris. Reconstructing Project Management. Chichester: Wiley-Blackwell, 2013.
- Project Management Institute. A Guide to the Project Management Body of Knowledge (PMBOK® Guide). 5th ed. Newtown Square, PA: Project Management Institute, 2013.
- W. R. Scott, R. E. Levitt and R. J. Orr. Global projects: Institutional and political challenges. Cambridge: Cambridge University Press, 2011.
- A. J. Shenhar and D. Dvir. Reinventing Project Management: The diamond approach to successful growth and innovation. Boston: Harvard Business School Press, 2007.
- V. Zerjav, A. Edkins and A. Davies. Project capabilities for operational outcomes in inter-organisational settings: The case of London Heathrow Terminal 2. International Journal of Project Management, 36:3 (2018), 444–459.

Association for Project Management

Ibis House, Regent Park,
Summerleys Road,
Princes Risborough,
Buckinghamshire HP27 9LE

Tel (UK) 0845 458 1944
Tel (Int) +44 1844 271 640
Email info@apm.org.uk
Web apm.org.uk

apm RESEARCH

APM Collaborative studies

APM Collaborative studies include research- and/or policy-based content by APM and like-minded organisations and individuals. The aim is to develop and generate innovative studies that help promote a profession built around learning and collaboration.

This expert report on project management was commissioned by the Edinburgh Tram Inquiry to address general issues about the nature, purpose and application of project management, as well as specific questions about programme management and risk management. This report has been adapted by APM and the author to help improve the delivery of projects and inform understanding.

For further information, please visit **apm.org.uk/research**

Please contact us with your views and suggestions:
research@apm.org.uk