

# Planning Support Systems for Complex Infrastructure Development

Dissertation

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# Abstract

As projects become larger the complexity faced by engineers increases and the importance of successful project management techniques has never been greater. In most cases (up to 75 percent of complex projects), the project with budgets greater than \$500 million is considered as complex projects (Engineers Australia, 2014). Engineers Australia (2014) identified that the massive failure rates of complex projects are due to inadequate communication, critical skill and knowledge gaps, or poor conceptual planning as well as “ineffective transfer of lessons learnt between similar projects”. All the factors are linked with the effective and efficient decision-making during planning faces of a complex project. The planning support system can assist decision-makers to make decisions under uncertainty. The aim of this thesis is to provide a basis for beginning and experienced engineers exposure to complex project management methods, and support systems that can be followed.

**Keywords:** Complex Project Management, Planning Support Systems.

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# 1 Introduction

Complex project management has been gaining prominence in the field of project management in recent years and continuing research and improvements have been sought to improve project outcomes. Traditional project management has been built around rigid, inflexible frameworks where round pegs are forced through square holes. This can work for smaller, low-complexity projects, however as complexity and budget begins to increase, it is necessary for flexibility to be available for the project management team to succeed.

The primary objective of this dissertation is to provide beginning and experienced engineers with potential tools, processes and considerations that should be made when planning for complex infrastructure projects. The focus of this has been around tools and support processes that can be employed to assist in efficient, effectual, and consistently managed projects.

## 1.1 What is Complex Project Management

How is a complex project different to a complicated one? With general project management, projects are approached from the beginning of a project with assumptions being made and the task is defined. When any issues arise the process of Monitoring and Controlling is used to return a project to its initial goal. A project is in a continuum between control and chaos, with simple projects at the control end and out of control projects at the chaotic end (Remington 2011). A complex project is one where the outcomes become difficult to predict with certainty, due to difficulty in defining the projects goals or a lack of knowledge of methods needed to deliver the project. This also means that as a project manager becomes more experienced, complexity can reduce because of their awareness of responses available to them.

The following areas that contribute to a projects complexity have been identified (Remington 2011).

**Uncertainty** which requires being identified when the path or destination of the project is no longer clear. It can occur when information is lacking or inadequate, details are ambiguous, complicated or unpredictable (Brashers 2001) also found that project members doubting their personal knowledge or the knowledge of their field on the subject. A projects lack of certainty will also lead to issues with trust with personnel lacking confidence in the team and their leadership. (Geraldi & Adlbrecht 2007)

**Cause and Effect** When projects become quite large with multiple key decisions between stakeholders and the project team a project can become enter 'non-linearity' where cyclical chains of events reinforce each other, often caused by technical complicacy, unclear decision-making or unexpected environmental changes (Geraldi & Adlbrecht 2007).

**Project Factors** Complexity factors include the key personnel's experience, project size, organizations' structure, technical challenges and time-related issues. A lack of experience with executives and unwillingness to employ experienced personnel along with optimism, pressure to begin projects and lack of acknowledging risks.

**Technical Difficulties** Perhaps the most expected project complexity comes from technological uncertainty and novelty (Pundir, Ganapathy & Sambandam 2007). When projects begin to face technological uncertainty teams can often start feeling issues with trust.

One of the most important aspects of successful project management is recognizing when complexity occurs (Remington 2011). When key people involved in the project are made aware that a project is more than simply complicated, the desired outcomes of a project become more likely. As project managers gain more experience they can recognize the complexity; however, other people associated with a project can struggle to comprehend the potential issues. This is why the use of tools or framework to identify not only how to deal with complex project management but also when a project is likely to become complex.

A large obstacle for project managers of complex projects can come from company executives or stakeholders who can be unable to grasp the complexity and (Helm & Remington 2005) found that leaders of successful complex projects succeeded by working around executives, rather than with. A complex project can result in teams becoming confused, distressed or losing confidence when a problem cannot be simplified.

## **1.2 History of Project Management**

The fundamentals of project management have been used since 2570BC with the construction of the great pyramids. In 1922 Henry Gantt, known as one of the forefathers of modern project management, developed his self-named 'Gantt Chart' to aid project scheduling (Clark, Polakov & Trabold 1922). One of the earliest major uses of the Gantt Chart was the Hoover Dam in 1931. In 1940 Dupont Corporation developed the Critical Path Method managers use to analyse flexibility of activities, originally developed to streamline the shutting down of chemical plants it was later used with for the Manhattan Project (Thayer 1996). Seeing the growing scale and importance of successful project management in 1956 The Association for the Advancement of Cost Engineering (ACEE) formed. This non-profit association began publishing technical journals for project management and now provides certifications for project managers (Haughey 2010).

In 1958 the US Navy developed the Program Evaluation Review Technique (PERT) for the development of the Polaris-Submarine weapon system. PERT is a decision-making tool designed to save time for programs with time as a critical factor (Stauber, Douty, Fazar, Jordan, Weinfeld & Manvel 1959). The US Military then furthered project management in 1962 when they developed the Work Breakdown Structure (WBS) as an extension of their work with PERT, a method of splitting large projects into well defined phases, deliverables

and work packages. WBS focuses on the end products or outcomes rather than the work required, allowing costs to be better planned and easy assignment of tasks (Haughey 2010).

The International Project Management Association (IPMA) founded in 1956. The first project management specific association, formed in Vienna to enable sharing of information. The Project Management Institute (PMI) was launched in 1969 as a non-profit to promote Project Management (*PMI Founders* n.d.), PMI are now the publishers of the Project Management Body of Knowledge (PMBOK), which is one of the essential tools for modern project managers.

The Theory of Constraints (TOC) was developed by Eliyahu Goldratt in 1990. TOC is a process to identify project constraints and restructure an organisation following the stems he outlined (Goldratt 1990). TOC was later used as a basis of Critical Chain Project Management (CCPM) in 2000. CCPM unlike PERT or Critical Path is used to keep resources evenly loaded, for projects with more flexibility with time management with less flexibility of resources (Steyn 2002).

PROMPT II IN the C(CTA) E(nvironment) PRINCE was developed from the earlier method of PROMPT II in 1989. The United Kingdom Government developed PRINCE pushed the idea of ‘assuring progress’ however it gained a reputation for being too rigid and lacking usability with smaller projects leading to the 1996 revision PRINCE2 (Haughey 2010). Also in 1996 the first ‘A Guide to the Project Management Body of Knowledge (PMBOK Guide)’ was published by the PMI. The PMBOK contains generally recognised best practice and forms the basis of knowledge for many modern Project Managers. In 2008 the American National Standards Institute (ANSI) and in 2011 the Institute of Electrical and Electronics Engineers (IEEE) recognised PMBOK as a standard for management (Haughey 2010).

In 2012 the International Organisation for Standardisation published ‘ISO 21500:2012, Guidance on Project Management’. The standard was developed for all organisations and project complexities, size and durations (Haughey 2010).

### 1.3 Motivation

As projects become larger and the complexity faced by engineers to manage them increases the importance of successful project management techniques has never been greater. Up to 75 percent of complex projects with budgets greater than \$500 million fail (Engineers Australia, Society, Society & for Project Leadership 2014). Engineers Australia attributed the massive failure rates to inadequate communication, critical skill and knowledge gaps, or poor conceptual planning as well as “ineffective transfer of lessons learnt between similar projects”. The aim of this report is to provide a basis for beginning and experienced engineers exposure to Complex Project Management methods, and support systems that can be followed.

## **1.4 Aims and Objectives**

Project complexity continues to rise and project management approaches have not kept pace with profession developments. The necessary tools and processes to successfully manage a complex project already exist, however project managers are often unaware or overwhelmed by them. The aims of this dissertation are to create a suite of project tools and processes that will contribute to a reduction in project complexity and improvement of complex project outcomes, and to provide an introduction to complex projects and raise awareness to the potential issues that can be encountered when managing them.

**The research objectives are:**

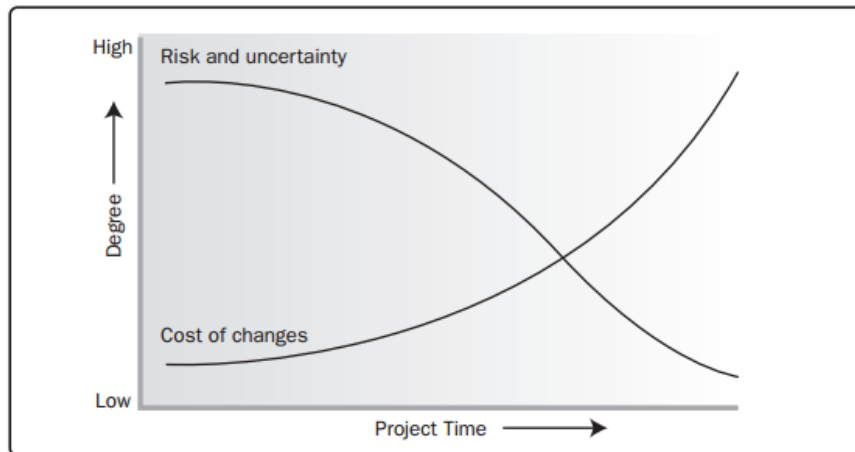
1. Research existing Complex Project Management tools and techniques to establish a basis for their implementation.
2. Analyse the various tools and attempt to select Complex Project Management methods that only apply specifically to Civil and Structural Engineering management.
3. Outline existing Complex Project Management tool and link them to identified categories.
4. Design a useful flowchart that an Engineer without any necessary previous knowledge would be able to use to implement Complex Project Management methods.

## **1.5 Project Failure**

A project can fail for many reasons, if the project delivers the wrong thing for the purpose, typically caused by issues with initial requirements analysis, impossible goals it's important that the requirements are thought through past the high level. By exploring assumptions that have been made rather than listing them it can be possible to reduce that risk. Ensuring interface issues are discussed, adequate contingency has been requested, it is important that the plan is realistic but it needs to be thorough because changing a project becomes more difficult as time goes on.

Scope creep can lead to uncertainty of the project team members. Scope creep is often a result of poorly defined requirements from project initiation. The project manager must understand the clients ideas. The client tells the project manager their wants but the project manager must work with the client to clearly understand their needs. This action helps to minimise scope creep as the client tries to modify their original scopes. Creep can also result from poor change control, communication, and weak project management resulting in the potential for cost overruns and scheduling.

The following findings were collated in The Standish Groups CHAOS Summary 2009



**Figure 1.** Cost of Changes vs Project Time

- 32% of all projects were successful, meaning delivered on time, on budget, with required features and functions.
- 44% were challenged; these projects were late, over budget, and/or with less than the required features and functions.
- 24% failed which was denoted by those projects that were canceled prior to completion or delivered and never used.

“These numbers represent a downtick in the success rates of the previous study, as well as a significant increase in the number of failures, they are the low point in the last five study periods (1994-2009). This years results represent the highest failure rate in over a decade.” (Crear, 2009)

“Up to 75 percent of complex projects with budgets greater than \$500 million fail.” (Engineers Australia et al. 2014) Which they defined as exceeding the original budget or schedule by 25%. The Mastering Complex Projects: Principles for Success and Reliable Performance: White Paper, 2015 identified many reasons for project failure, lack of communication among stakeholders and participants; critical skills and knowledge gaps for key personnel, poor conceptual planning, insufficient implementation of project controls and risk management; and the ineffective transfer of lessons learnt between similar projects.

The white paper also identified the common properties of the 25% of complex projects that succeed “emphasis placed by project leaders on collaboration, communication, monitoring and integration: from initiation to project commissioning.” They added that it can be crucial to success that a project is separated into two stages: shaping, and implementation. Shaping is the stage that internal and external stakeholders are brought together to define the requirements, this act can have a large effect on scope creep and mitigating the risk. The implementation stage is achieving objectives identified within the shaping stage with the Project Shaper role providing assistance to the project manager.

Risk management is also a critical component of successful complex projects. Identifying

showstoppers during project initiation can be crucial for project success. Differing perspectives of project stakeholders should be taken into account. A showstopper is defined as “a situation or issue that is blocking progress partially or fully and needs immediate attention from one or more stakeholders to clear and move forward.” (Lexicon 2012). Project resources should be allocated to establish initial conditions and potential failures.(Bear 2015) Complex projects are inherently higher risk projects and provision for unexpected risks in scheduling and budget.

Monitoring a projects progress is important to report progress to stakeholders and identify areas of concern or possible optimization. Identifying thresholds for when a control is needed can help minimise the risk of issues going unnoticed, uncorrected or ignored. A projects failure may be (Bear 2015)

- failure to meet stakeholder expectations or needs
- failure to meet performance, technical or functional specifications
- significant overruns in either the schedule of the project, its cost or both of these factors
- collapse of the project before completion

Failure to correctly define the projects boundaries and scope at project initiation, groups operating in isolation, inadequate engagement of stakeholders, high level management, scheduling failing to clearly link to deliverables, and focus on analysing risk rather than mitigating.

## 1.6 Thesis Structure

**Chapter 2: Literature Review** The literature review is the research conducted on the literature across each source of information used for the project.

**Chapter 3: Methodology** The methodology chapter presents how this thesis has been undertaken. The review of secondary sources to ensure they are appropriate for this thesis and the qualitative approach used.

**Chapter 4: Findings** The findings chapter is the core of the dissertation. The chapter includes discussion on:

[General Project Complexity] Possible causes of project complexity include the key personnel’s experience, project size, organizations structure, technical challenges and time-related issues. A lack of experience with executives and unwillingness to employ experienced personnel along with excessive project optimism, and pressure to begin projects while failing to acknowledge the associated risks. This chapter addresses tools that may be used to reduce this ‘general’ source of complexity.

[Uncertainty] is a major source of complexity, and it requires early identification of when the path or destination of the project is no longer clear. It can occur when



information is lacking or inadequate, details are ambiguous, complicated or unpredictable (Brashers 2001) it has also been found that project members doubting their personal knowledge or the knowledge of their field on the subject can greatly impact the projects uncertainty. A projects lack of certainty will also lead to issues of trust with personnel lacking confidence in the team and their leadership. (Geraldi & Adlbrecht 2007)

[Technical Uncertainty] Perhaps the most common form of project complexity comes from technological uncertainty and novelty (Pundir et al. 2007). When projects begin to face technological uncertainty teams can often begin to have issues with internal project trust, self-doubt, and struggle to maintain their motivation.

[Cause and Effect] As the scale of a project increases and multiple key decisions between stakeholders and the project team occur throughout the project, the project can become 'non-linear' where cyclical chains of events reinforce each other, often caused by technical complicacy, unclear decision-making or unexpected environmental changes. The non-linearity of the project makes it difficult to evaluate actual project progress, recognise where resourcing is needed, and respond to issues appropriately. The 'effect' of 'cause and effect' can lead to massive budget and scheduling overruns, and even failure to solve the projects original need. (Geraldi & Adlbrecht 2007)

**Chapter 5: Conclusion** What is the significance of my findings on complex projects and what limitations have been identified with my research.

## **2 Literature Review**

### **2.1 Introduction**

This dissertation's literature review describes the sources used in the process of this research. The targeted literature and the methods used to refine the sources used is discussed in the project methodology, this section specifically examines the specific key sources referenced throughout the dissertation.

### **2.2 Leading Complex Projects**

The work compiled by Kaye Remington in *Leading Complex Projects* explores the importance of key personnel with empirical research into successful complex projects. The project was informed by interviews with 70 leaders of complex projects and explains best practice. Remington discusses the challenge of dealing with uncertainty inherent in accelerating social, organisational and technological change and expanding cultural diversity. A holistic approach is recommended in dealing with this complexity. The human factor including the people involved, the ways in which they communicate and the relationships they forge constitute the behaviour and combined culture of any organisation or project creates challenges unless leadership can transform these factors.

Remington (2011) states indicators of project complexity, including uncertainty, trust and difficulty in linking cause and effect. In a complex project environment, communication is the most frequently cited cause of project failure and can be promoted by modeling of skills such as using a problem/challenge frame, self-reflection and articulating meaning.

Accountability and the ability to define success criteria are issues that can be managed by a flexible structure with a foundation of trust that supports flexible problem solving in order to make success possible. Clarke (2010) finds that the emotional awareness of project managers may be a factor that helps to explain how project managers may arrive at decisions that affect their interpersonal relationships on projects and therefore, traditionally rational approaches to project management are limited.

Winter et. al. (2006) discuss a new class of projects, moving away from a traditional 'engineering' view of projects to more business oriented projects, in which the primary concern is no longer the capital asset, system or facility etc, but increasingly the challenge of implementing business strategy, improving organisational effectiveness, and managing the realisation of stakeholder benefits. Kolltveit, Karlsen and Gronhaug (2007) discuss the move over time from a task perspective to a new leadership perspective. In these new cases, strategic management approaches must be used. In situations where conventional project management principles prove inadequate, typically where objectives are uncertain, a move to new approaches is necessary (Lichtenberg, 1989). Saynisch (2010) asserts that asserting that traditional project management cannot fulfill the challenges and requirements

for mastering increased complexity in society, economics, and technology and that a new paradigm in project management is necessary.

Kreiner (1995) explores the situation where the original outcomes of a project may become irrelevant over time, presenting challenges to project management that stem from the possibility of relevance becoming eroded in the course of implementation. This may reflect changes in customer preference, competitor strategies or corporate commitments, but displays the need for managers to be flexible.

## 2.3 Tools for Complex Projects

Tools for complex projects is another publication by Remington and written before *Leading Complex Projects*, this book utilises modern project management and complexity theory to provide fourteen project tools applicable to different project stages. There are four dimensions of complexity defined – structurally, technically, directionally and temporally complex projects. Managing these complexities is an important consideration that has traditionally been linearly managed, which, while often successful, does not meet the needs of all projects and should not be unilaterally applied. Rather than a linear model, conceiving projects as systems may assist the project manager in drawing flexibly and dynamically from a range of methods in order to deliver satisfactory outcomes to stakeholders. This idea is supported in Winter and Checkland (2003) which states that a ‘hard’ system thinking, or conventional approach, is no longer sufficient, and that ‘soft’ systems thinking is increasingly necessary and demanded.

The goals-and-methods matrix for coping with projects with ill-defined goals asserts that projects can be judged against two parameters: how well defined are the goals, and how well defined are the methods of achieving them (Turner, Cochrane, 1993). This method outlines four types of projects: (1) Goals and methods are well defined; (2) Goals are well defined, methods are not; (3) Goals are not well defined but methods are; and (4) neither goals nor methods are well defined.

Using this view, Turner and Cochrane assert that three breakdown structures are relevant – the Product Breakdown Structure defining deliverables, the Organisational Breakdown Structure identifying resources, and the Work Breakdown Structure, a matrix of products and activities. Turner and Cochrane argue that only on Type -1 projects is it possible to plan the project in terms of the activities to be undertaken. For types 2, 3 and 4, Turner and Cochrane suggest milestone planning.

A complexity theory framework is provided by Pundir et al (date) as an alternative to the traditional models, characterised as: (1) rational (Lundin, 1995) and normative (Packendorff 1995); (2) having a positivist ontological stance (Johnson and Duberley, 2000); and (3) having a scope that can be managed by using work break down structures (Turner, 2006). Pundir et al state that complex projects cannot be predicted but will emerge from the iterations between the projects elements and the environment. The authors analyse project failures that can be attributed to a failure in traditional project management and conclude

that the theory of project management continues to evolve.

Building on the idea that uncertainty could be considered a dimension of project complexity (Williams), Geraldi distinguishes the complexity of fact and the complexity of faith (Geraldi and Adlbrecht, 2007) as well as the complexity of interaction. The authors examine the complexity of the interface between people and organisations which contribute to overall project complexity. Aspects of this interface which add to complexity include number of contractors, influence of politics, technological newness of the project and dependency on other departments (Geraldi and Adlbrecht, 2007) which are important considerations for the project manager.

Brashers (2001) discusses the complexity of human communication, and the challenges of dealing with uncertainty in life. Pertinent to this thesis is the discussion of organisational communication where uncertainty about how to do a job, what to expect in performance appraisals and how to manage relationships with others (Teboul, 1994, in Brashers, 2001) is able to be managed through structure, routines and social support, and are therefore an important consideration for project managers.

## **2.4 Mastering Complex Projects**

The ‘Mastering complex projects conference’ white paper foregrounds the importance of collaboration, communication, monitoring and integration: from initiation to project commissioning for a successful complex project. Conversely, project failures can occur for many reasons including lack of communication among stakeholders and participants; critical skills and knowledge gaps for key personnel; poor conceptual planning; insufficient implementation of project controls and risk management; and the ineffective transfer of lessons learned between similar projects. These are industry-wide concerns.

Issues around the reflectiveness of practitioners as an approach to address the challenges of developing competent project managers in a world exhibiting increasingly complex project challenges, and when skilled resources at all levels are often increasingly scarce are explored in Crawford, Morris, Thomas and Winter (2006) and further reflect a move to a more people-focused approach to project management.

Project leadership is foregrounded as an important consideration for success, as there are key areas of leadership and collaboration expertise that need to be developed not just within projects or organisations, but across the whole industry. A collaborative approach which combines leadership, knowledge and skills, front end shaping, professionalism and other systems is a major contributor to successful complex projects. Shenhar (1999) further argues for a move from a one-size-fits-all approach to a view that different projects should be managed in different ways.

## 2.5 PRINCE2

The PRINCE2 guide is an interdisciplinary guide for project management. Used for PRINCE2 certification. PRINCE2 is described as a structured method for effective project management and provides a common language between organisations and with external suppliers providing a mechanism to define what the project is trying to achieve and the rationale and business justification behind it (PRINCE2). The manual identifies characteristics that define a project change, temporary nature, cross-functional, unique and uncertain. The PRINCE2 manual further states the benefits of a management structure as promoting effective communication explicit recognition of project responsibilities. There are seven principles which form the basis of a project:

- Continued business justification - Learn from experience - Defined roles and responsibilities
- Manage by stages - Manage by exception - Focus on products - Tailor to suit to project environment

These principles define a PRINCE2 managed project. The manual defines roles that can be divided according to the project's needs, for example, team manager who ensures production of those products assigned to the project manager or project support which may include :administrative services or advice and guidance on the use of project management tools or configuration management planning or risk assessment. The manual is clear that people are crucial to the success of a project. It is not enough to have the required processes and systems in place; if the people on a project do not work effectively together, then the chances of the project's success are severely limited.

## 2.6 The Guide to the Project Management Body of Knowledge

The Guide to the Project Management Body of Knowledge is an industry standard in project management, recognised by IEE and ANSI and is overseen by the Project Management Institute. The PMBOK Guide distills 47 project management processes into five Process Groups: Initiating, Planning, Executing, Monitoring and Controlling, and Closing (PMBOK) as well as identifying thirteen Knowledge Areas (Integration, Scope, Time, Cost, Quality, Human Resource, Communications, Risk, Procurement, Stakeholder). In a comparison of PRINCE2 and PMBOK, Wideman (2002) states that the PMBOK guide takes the best approach for purposes of teaching the subject content of each knowledge area, but is not so affective when it comes to providing guidance for running a particular project and that the PMBOK is written from the project manager, rather than the supplier or seller, perspective.

The PMBOK guide makes the assumptions that project management knowledge is applicable to all sorts of projects in all sorts of industries and environments (Packendorff, 1995) and reflects a model of project management as a 'universal' approach. Packendorff argues for a focus on the deliberate social interaction occurring between people working together to accomplish a certain, inter-subjectively determined task (Packendorff, 1995).

Zwikael further analyses the PMBOK using a field study of 783 project managers to identify the most impactful Knowledge Areas on project success. These were found to be Time, Risk, Scope and Human Resources (Zwikael, 2009).

## **2.7 On Faith, Fact, and Interaction within projects**

On faith, fact, and interaction in projects was written by Geraldi, Joana G and Adlbrecht, Gerald and published in 2007. The article is focused on the management of project complexity caused by three factors: Faith, Fact, and Interaction. The journal authors conducted a study of seven different engineering and construction projects to analyse the evolution of project complexity through a projects life.

Geraldi is a senior research fellow at the International Centre for Programme Management in the UK, Adlbrecht is a professor of the University of Siegen, Germany, and Head of Department of International Project Management.

## **2.8 Effective Sponsorship**

Effective Sponsorship: An Evaluation of the Role of the Executive Sponsor in Complex Infrastructure Projects by Senior Project Managers was published in the Project Management Institute, 2005. The journal explains the importance and requirements of effectively sponsor a project and encourage success. The article examines existing literature through Grounded Theory and interviews with 30 project managers and directors.

## **2.9 Systems Engineering Principles and Practice**

Systems engineering principles and practice is a foundational textbook on systems engineering. The textbook was originally an expansion on the John Hopkins University Master of Science Program in Engineering. The graduate-level textbook provides fundamental explanations on systems engineering approaches. Written by Kossiakoff, Alexander and Sweet, William N and Seymour, Sam and Biemer, Steven M, and published by John Wiley & Sons in 2011.

## **2.10 Towards a complexity framework for managing projects**

Towards a complexity framework for managing projects written by Pundir, Ashok K and Ganapathy, L and Sambandam, Narayanasamy, and published in the Journal Emergence: Complexity and Organization in 2007. The journal analyses 60 projects across four continents to measure complexity of large capital projects. The journal analysed the difference

between successful and unsuccessful projects. The paper makes suggestions on project approaches.

## **2.11 Project Management applications of Theory of Constraints**

Project management applications of the theory of constraints beyond critical chain scheduling written by Steyn, Herman and published in the International Journal of Project Management in 2002. The research suggests a method for the application of Theory of Constraints for more than just project scheduling.

## **2.12 Project Management: The managerial approach**

Project Management: The Managerial Approach, written by Larson, E. W. and Gray, C. F. is a “marked-leading textbook on the subject” of project management. The textbook links its chapters to PMBoK certification for the Project Management Institute and provides steps to successfully managing projects.

## **3 Methodology**

### **3.1 Introduction**

The methodology outlined in this section was used as the basis for the analysis of literature for the research presented. The dissertations methodology formed assisted in creating a rigidity of processes and improving the quality of outcomes. A systemic literature review has been used to provide the means by which current best evidence from research can be integrated with practical experience and human values in the decision making process.(Dybä, Kitchenham, Jorgensen et al. 2005) Systemic literature reviews involve several discrete activities, planning the review, conducting the review, and documenting the review. By aggregating evidence through different techniques with different contexts it is necessary to create a structure around assessing the literature and how decisions on what literature will be used is going to made.

To perform this process more than 80 sources were examined and reduced to 42 ultimately used. The process in which the sources were compiled and reduced is detailed throughout this chapter.

### **3.2 Qualitative Data Analysis**

This dissertation will use a systemic qualitative literature review. This method is useful in collecting and judging the findings of primary studies and has become a cornerstone of the evidence-based practice and policy movement (Dixon-Woods, 2006) and further, qualitative methods such as this can enhance the link between evidence and practice (Dixon-Woods, 2008). Project management is an important consideration for modern organisations and the structuring of projects is a key challenge as the pace of change accelerates projects are the means by which we introduce change (PRINCE2). As such, the examination of methods and models for complex project management is an important task. There are several guides for complex project management that will be examined in this dissertation.

The overall questions are:

What considerations does a project manager need to be aware of when selecting an approach to complex project management?

What existing tools are available for project managers to use?

What is the major source of complex projects failing? and,

Where can this research be improved in the future?

An integrated approach using thematic analysis, elements of grounded theory and narrative analysis approach is used to develop a theory from the data collected using existing



literature, distilled into themes and analysed. This integrated approach is used in Floersch, Longhofer, Kranke and Townsend, and produces a “multidimensional view”. The methodology is ideal to produce a view which uses the knowledge used and created - seeing patterns (with thematic analysis), relating and connecting patterns (grounded theory) and with “temporality and plot” (narrative analysis) (Floersch, Longhofer, Kranke & Townsend 2010).

Kincheloe and Tobin describe knowledge as ‘stripped of its meaning when it stands alone’ (2006: 11), knowledge which is situated in context and within relationships is rich in meaning, and thus research should be considered with this in mind. In a qualitative research project which uses analysis, deep reflection is necessary to establish an accurate, defensible and credible picture of the scenario or experience described.

### 3.3 Data Collection

The process of researching this dissertation began with the question: What are the most important considerations for a project manager? To write something which was accessible, relevant and useful to project managers in real contexts required deep reflection on source quality. The first decision was my key concepts. I decided that these would be reexamining project management and new approaches for project management. Next, I developed appropriate search strings.

Each source that was found was read through and identified if the literature addressed one of the guiding questions. For literature regarding project failure there was a weighting applied to Australian based papers due to their relevance to the dissertations target audience. Project tools that were heavily focused on Information Technology project management were also excluded due to the dissertations focus on infrastructure projects.

**Table 1.** Literature Review Key Words

Project Management	Project Management Reexamine
Project Management New Approach	Project Management Change
Project Management theory	Project Management Theory Comparison
Project Management complexity	Project Management Perspectives
Complex Project Management	Systems Engineering
Complex Projects	Stakeholder Engagement
Risk Management	Project Failure
Major Projects	Complex Project Failure

Once the sources had been accessed they were evaluated by considering their title, keywords and abstract. They were then examined using the perspective described in Svejvig et al which contrasts classical and ‘new’ project management approaches.

The key data from each study was the Source, question the source addressed, authors country they were located, quality evaluation, and if the study was theoretical or practiced.

Resources searched for using the key search terms included:

- USQ electronic library
- Google Scholar
- Engineers Australia Technical Journals
- IEEE Explore
- Science Direct

### **3.4 Data Analysis**

Thematic, inductive analysis is primarily used to categorise data into key themes, or as a process of “encoding qualitative information” (Boyatzis, 1998). The sources were grouped and the items were coded. Connections between certain statements were used to connect ideas to start collecting similar notions and created some initial ‘themes’. A focused thematic analysis was used, where the major considerations for a project manager were sought out, in order to answer the research question.

The categories which emerged were:

1. Alternative perspectives
2. Reality of projects
3. Complexity and uncertainty
4. Social and political impacts
5. Context (environment, organisational strategy)

Upon examination of the literature as well as the themes which became apparent after analysis, it is clear that it is not only the technical or technological elements in a project which make a project complex. De Bruijn et al. (1996) determined three dimensions of complexity: technical, social and organisational. As such, a framework which covers all three of these elements which add to project complexity is recommended.

### **3.5 Limitations of Methodology**

The research was conducted over several months however it is possible that some key studies were not found due to a failure of search methodology, publication locations, or researcher bias. The data that was collected and compiled contained some very different viewpoints of improving project management and there may have been data aggregation throughout the

project. The field of complex project management is also very new, and emerging trends and research being undertaken may come to very different conclusions.

Whilst the research was undertaken according to the established criteria, the lack of experience of the researcher may have resulted in the misidentification of literature. If the research was conducted by more than researcher it is possible more bias could have been removed from the data selection.

## 4 Findings

### 4.1 Introduction

Existing best practice for project management is not always appropriate for complex projects. Complex projects need a project structure to be tailored to the individual project to meet stakeholder requirements. Monitoring and communication must be maintained throughout the project to ensure the project continues towards the objectives. (Bear 2015)

**Flowcharts of Findings** To assist in the usage of this dissertations findings four flowcharts have been created to assist project managers and members of project teams in their identification and application of the tools. The flowcharts have been created too help guide the usage of the project tools.

**General Project Tools** These tools or processes have been identified as required for all complex projects. They are generally tools that are currently used in all levels of project management, with the exception of earned value methods, shaping, and collaborative project structures. If none of the other project tools are used on a complex project, these will still contribute positively to a projects success and outcomes.

**Project Uncertainty** When a project manager identifies the project is encountering project uncertainty the tools and processes in this flowchart help to reduce that uncertainty. Clearly setting expectations, assessing issues, and other processes assist in reducing or removing project uncertainty.

**Technological Uncertainty** Within project uncertainty a subset of complexity exists for technological uncertainty. These tools and processes assist in reducing the issues that are caused by having technological unknowns. Clearly defining roles to minimise project team uncertainty, analysing what is known about the uncertainty faced and other actions can help in the mitigation of this complexity.

**Cause and Effect** The final identified source of complexity is project non-linearity. These tools are intended to help provide a more rigid structure for the project team to operate in by controlling progress and monitoring project progress and communication tightly.

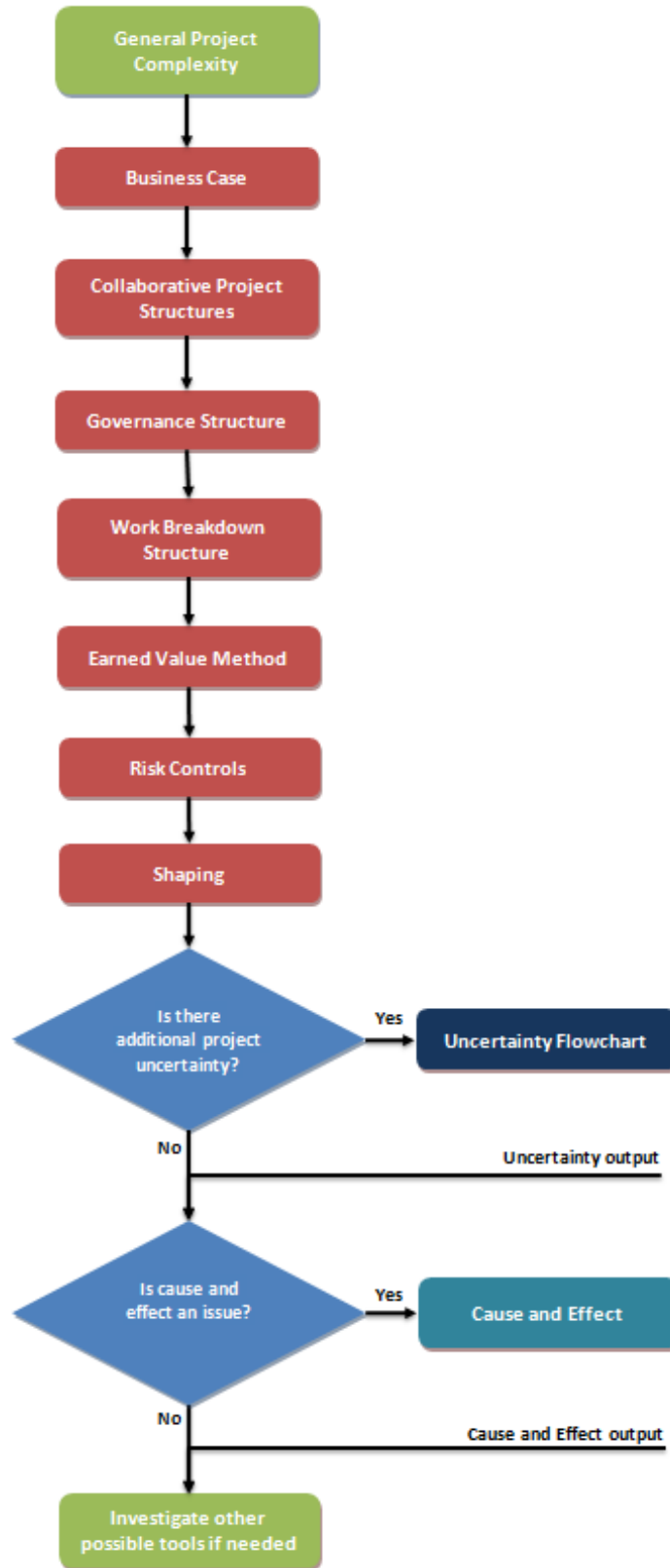


Figure 2. General Project Complexity Flowchart

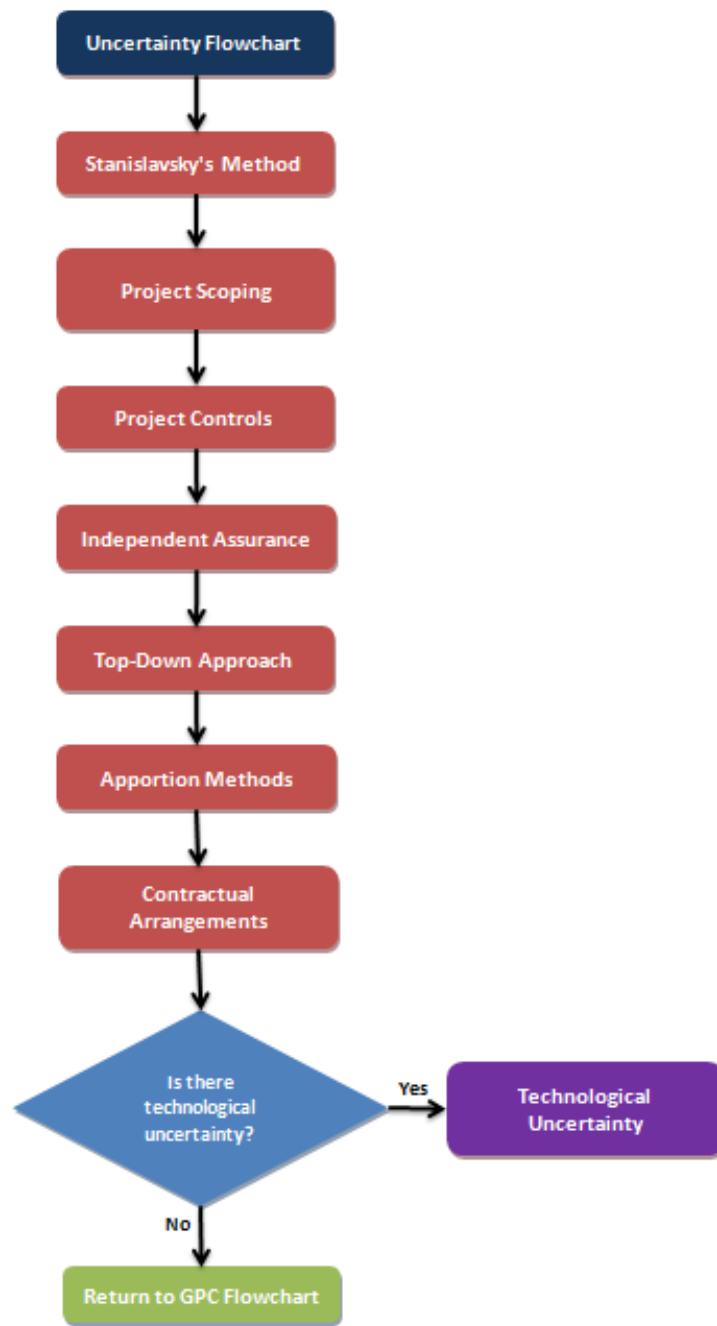


Figure 3. Project Uncertainty Flowchart

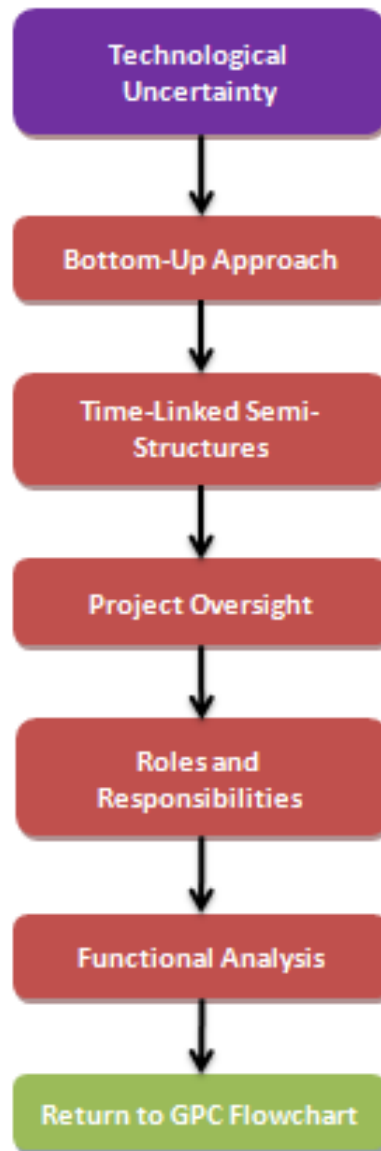


Figure 4. Project Technological Uncertainty Flowchart

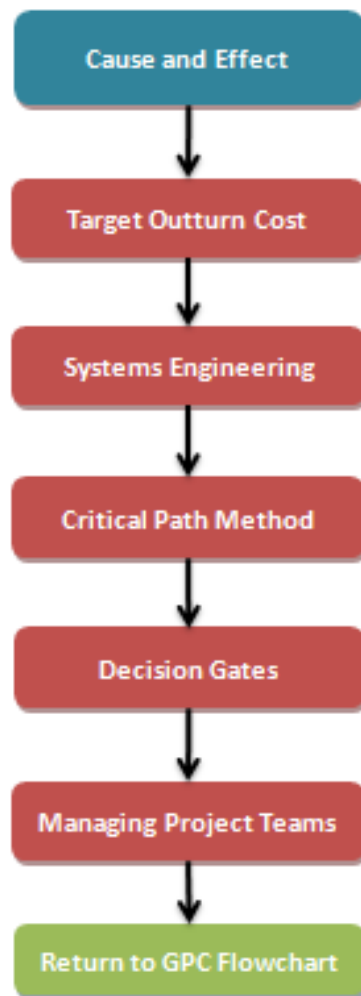


Figure 5. Project Cause and Effect Flowchart



## 4.2 General Project Complexity

Possible causes of project complexity include the key personnel's experience, project size, organizations structure, technical challenges and time-related issues. A lack of experience with executives and unwillingness to employ experienced personnel along with excessive project optimism, and pressure to begin projects while failing to acknowledge the associated risks. This chapter addresses tools that may be used to reduce this 'general' source of complexity.

### 4.2.1 Business Case

Prior to the project scoping, it is recommended that a business case is carried out (Murray et al. 2009). The business case should contain the need to undertake the project, the risks, potential budget, project duration (Murray et al. 2009), market demand, organizational need, customer request (if applicable), technological advances, legal requirements, ecological impact, or social needs of the project (Project Management Institute 2013). For considering potential solutions to the deficiency, it is recommended that at least three options are considered:

- Do nothing,
- do the minimum,
- or do something (Project Management Institute 2013).

The risk analysis should be high level and focus on effects on business objectives, and possible impacts on costs to mitigate the risks. The project schedule should also be considered when comparing options, and the earliest or latest start and finish times for the options should be considered. One of the most important components of a business case is confirmed there is an actual need for a project. Needs analysis examines whether there is a gap within the organisation, and that the amount of effort to resolve the issue is feasible (Kossiakoff, Sweet, Seymour & Biemer 2011). The needs analysis can help organisations assign budgets to future potential projects and minimizes the risk of totally unfeasible works being attempted. The analysis with typically examine existing market solutions, deficiencies, and possible new solutions.

The information for the needs analysis can be broken down into four steps (Kossiakoff et al. 2011).

**Operations Analysis** Analyse the need for a new solution, this may be due to a deficiency or potentially greater efficiencies. Examine the solutions whole of useful life, and attempt to define quantitative operational objectives.

**Functional Analysis** Translate the objectives into requirements of the solution, allocate these requirements to subsystems in a modular configuration.

**Feasibility Definition** Visual the subsystems needed for the project to function and define a feasible concept with estimated costs against performance.

**Needs Validation** Consider operational scenarios and external factors, define selection criteria, demonstrate why the solution is the best choice, and formulate a case for why the project is needed.

#### **4.2.2 Governance**

Project Governance is different to Corporate Governance. The basic goals of project governance is to realise the planned benefits through evaluation of proposals in relation to strategic alignment, defining critical success factors, gathering business support, defining key roles and responsibilities of the project, enabling project resourcing, managing key stakeholders, monitoring progress, and enhancing delivery capacity. (Remington 2011)

For effective project management it is critical that the position is provided with appropriate governance structure. The governance structure should establish a process for the team to follow from as early in the process as possible. (Kevin Fickenscher & Michael Bakerman 2011) The governance structure should provide clear accountability for all roles. The project sponsor or director should make it clear to the project manager what the outcomes are, their financial delegations, scheduling requirements, and any other constraints of the project. It is important to note that project governance is different to corporate governance, and is solely concerned with appropriate provision for the project. Key components the governance include clear definitions of key roles and responsibilities, enabling resources, managing stakeholders, monitor the scope, quality, budget and scheduling, define critical success factors, gather organisational support, and continue to improve delivery capability. (Remington 2011).

Governance in complex projects can require more than the single key person to be accountable for a project. Joint ventures or international partnerships governance structures are typically influenced by four main variables, corporate cultural differences, trust, procurement autonomy, and motivation. For projects involving large organisational cultural differences in practices and values it is critical that an appropriate governance structure is established. Traditional governance has several weaknesses when dealing with complex projects. It can be difficult to define a single point of accountability, assess the projects actual progress, provide systemic decision making, ensure truthful reporting, and a great deal of other issues. (Remington 2011)

Success Criteria for truly complex projects can be difficult to define or the method of achieving that goal. The criteria can also develop with time, adding to complexity. In volatile projects it can be difficult to anticipate the change to outcomes, especially in political or public sector projects. The difficulty in accountability and defining criteria means the governance must be flexible enough to respond appropriately. It's necessary for project success that the foundation is based on trust. To achieve this the projects must have achievable success criteria.

The governance team determines whether a project is meeting success criteria, however it can be difficult for them to know the true status of a complex project. Effective governance depends on successful communication, through relationships with the project teams and encouraging free and open dialog between the project team and the governance body. It is also the governance teams responsibility to make the project team aware of organisational progress that may impact the project, as changes to a projects strategic alignment can greatly impact a projects potential to succeed.

If the relationship between contractors and the project manager breakdown, enforceable and mutually acceptable legal frameworks can greatly help with a resolution. Cross cultural issues can also occur. The governance structures suggested by the PMI or APM are infused with liberal democratic principles (Verspaandonk 2001). The difference in cultural values between different countries can be very substantial, complex project involving a single nation can have difficulty in establishing effective governance, but in multi-national projects it can be almost insurmountable(Remington 2011). Developing a shared understanding of the projects motivation and local political processes can greatly aid project governance and accountability. (Remington 2011)

Governance also needs to be established from the project initiation. It is important that the project manager is provided with enough delegated power that they can effectively manage. Difficult project sponsors can cause many difficulties and if the sponsor lacks a real interest in the project then more rigid and invested people should be used to balance the steering group.

The selection of the project manager is a critical part of projects. The experience and relation to a project can drive it to completion but the manager shouldn't be the service owner. If the service owner also becomes the project manager other stakeholders can become neglected, there is less scrutiny on the project, and contingencies may be allocated to scope creep for the owners wants (Murray 2009). Environmental changes to a project may mean the planned benefits are no longer needed, which will lead to a necessary review of requirements and change in project scope. Good communication of a projects progress and identifying any issues early on can save a project (Murray et al. 2009).

The project management handbook PRINCE2 puts great emphasis on a projects governance. The PRINCE2 methodology can be used for projects of any scale, complexity or culture. PRINCE2 was developed from lessons learned and provides a framework of best practice. PRINCE2 focuses on seven principles they consider a must for success (Murray et al. 2009):

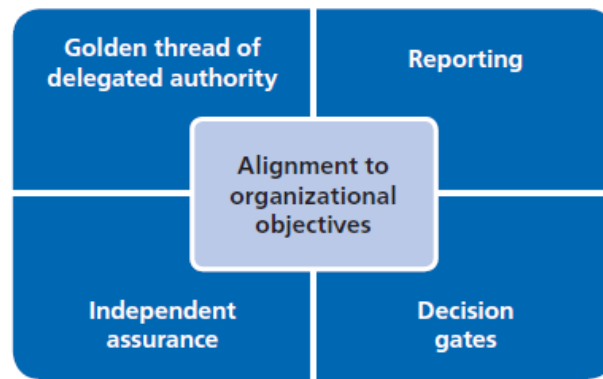
- Have continued business justification,
- learn from previous experience: lessons are sought, recorded and acted upon throughout the life of the project,
- have defined and agreed roles and responsibilities within an organization structure that engages the business, user and supplier stakeholder interests,
- be planned, monitored and controlled on a stage-by-stage basis,

- have defined tolerances for each project objective to establish limits of delegated authority,
- focus on the definition and delivery of products, in particular their quality requirements,
- be tailored to suit the projects environment, size, complexity, importance, capability and risk.

The seven principles provide a solid basis of governance and can be used to assess a projects management. APM has a special interest group that is entirely focused on a projects governance that has established their own 11 principles of governance (Weaver n.d.):

- The main board has overall responsibility for governance of project management
- The roles, responsibilities and performance criteria for the governance of project management are clearly defined.
- Disciplined governance arrangements, supported by appropriate methods and controls, are applied throughout the project life cycle
- A coherent and supportive relationship is demonstrated between the overall business strategy and the project portfolio
- All projects have an approved plan containing authorization points at which the business case is reviewed and approved. Decisions made at authorization points are recorded and communicated.
- Members of delegated authorization bodies have sufficient representation, competence, authority and resources to enable them to make appropriate decisions.
- The project business case is supported by relevant and realistic information that provides a reliable basis for making authorization decisions
- The board or its delegated agents decide when independent scrutiny of projects and project management systems is required, and implement such scrutiny accordingly
- There are clearly defined criteria for reporting the project status and for the escalation of risks and issues to the levels required by the organization
- The organization fosters a culture of improvement and of frank internal disclosure of project information
- Project stakeholders are engaged at a level that is commensurate with their importance to the organization and in a manner that fosters trust.

Alignment to organizational objectives: Organisational objectives are the foundation of all projects, and they set the documentation and planning from initiation. The importance of the alignment to project management rather than portfolio management is the ease a



**Figure 6.** PRINCE2 Governance (retrieved from Murray 2009)

project can demonstrate its alignment (Project Management Institute 2013). PRINCE2 addresses alignment issues with ongoing justification to ensure continued monitoring and informed decisions for management.

**Golden thread of delegated authority:** As Kaye Remington discussed the importance (and often difficulty) of a well defined single accountable person, a ‘golden thread’ represents the chain of responsibility from top to bottom and should clearly demonstrate what an individual’s authority is. The purpose is to prevent decisions being overturned which can lead to losses of confidence, trust and uncertainty. When power is not delegated appropriately organisations can lose control of work or prevent a project from being able to change. PRINCE2 addresses responsibilities with the importance of clearly defined roles and a ‘management by exception’ principle (Murray 2009).

**Reporting:** Reporting is critical to keep the directing and corporate management levels aware of the projects progress. PMBoK and PRINCE2 measure a projects progress by establishing methods to monitor and compare actual progress against planned scheduling and forecast viability. The project will also be given thresholds at which control measures or approval may be required to correct issues. A common method of measuring and assessing progress with scheduling and scope is the Earned Value method. Two types of reporting are time-based which involves progress against a previously agreed interval with Checkpoint Reports and Highlight Reports. Event-based reporting is completed when a stage is reached, a request for change or exceptions or a new risk has been identified. Exception reporting is based on the Event-based method and occurs when a project has deviated from a projects tolerance. The controls on reporting requirements will be captured in the projects documentation (Murray 2009).

**Independent assurance:** An independent check on the adequacy of the projects structure and systems. Assurance is the second layer of progress reporting outside of self-reporting and performed by an independent party. It should provide upper management delegating authority with transparency and reduces the risk of self-reporting abuse. The Project Assurance role is independent from the Project Manager, Project Support, Team Managers and other project teams. The Project Board is responsible for providing the Project Assurance role with their areas of concern: business, user or

supplier. The PA role may be filled by members of the corporate organisation taking specific roles (Murray 2009).

**Decision Gates:** A formal control point in a projects life cycle The delegated authority will only extend until the next decision gate and the authority is extended after review. They form a 'fail safe' for issues missed in ongoing reporting. The project is broken into management stages allows control points where projects status, Business Case, and plans are reviewed. PRINCE2 recommends four stages: approval to initiate, after initiation, one at each stage boundary and one at project closure (Murray 2009).

Senior management must be committed to governance of projects and ANDY MURRAY states Nearly every study into project management performance shows that appropriate senior management involvement directly correlates with successful projects. (Murray 2009)

The governance team is responsible for the identification and updating of key stakeholders, and managing their expectations. Often projects will communicate with the key stakeholders, ask them for input and then not engage with them at all throughout the project. (Remington 2011) Stakeholders can be categorized into either primary stakeholders, or secondary stakeholders. A primary stakeholder will usually be internal to the organisation or someone who interacts directly with the business which may include customers, employees or suppliers. The secondary stakeholders are those considered external to the project, they may be affected by the project but not engage directly with the product which can include media, or activist groups.

Typical stakeholders involved in a project are members of the project team, who complete or manage work for the project. Project sponsors who support the project and are invested in the success of the project, and project customers who help to guide the projects scoping and will ultimately be the user or owners of the projects product.

The governances implementation is critical to its success. The governance needs to sit between all key parties to prevent difficulties later in the project (Remington 2011). Professionally run workshops at project initiation to share values can prevent many complex projects risks. It will be more difficult to implement governance structures during the project than earlier. (Remington 2011).

The following governance standards have been suggested (Remington 2011).

- Standards of interpersonal behavior (honesty, trust, transparency).
- Problem-solving under conditions of certainty and uncertainty.
- Decision-making frameworks.
- Dealing with emergence (risk and learning opportunities).
- Roles, responsibilities and accountabilities.

- Procurement methods.
- Reporting protocols (owners, sponsors, project teams, stakeholders, including the media - internal and external reporting pathways).
- Security provisions (level of access to documents).
- Organisational values (safety, quality, budget, schedule).

Complex projects rely on a flexible structure that will allow the project teams to respond quickly. Adding restrictive controls to projects that are getting out of control can make the project more difficult to manage (Plowman & Duchon 2008).

Governance may be formed with existing management teams or governance boards within an organisation. Upper management should determine the most closely aligned body and secure agreement on the governance role, providing them with a charter, scope, and how they are integrated into the approval process. (Project Management Institute 2013)

The governance team then needs to set project boundaries for the organisations and stakeholders values. The governance body can then establish or approve appropriate KPI's. The governance should be inclusive at all levels and non-political. For large scale infrastructure with multi-owner or multi-national governance teams understanding of local networks and integration of agents is important (Remington 2011).

The two most critical roles requiring definitions have been identified (Remington & Pollack 2007).

**Project Manager** Research was conducted into the most important aspects of the project manager and identified the following attributes of successful managers (Remington & Pollack 2007).

- Developing creative project direction.
- Highly skilled with communication between all levels of the project.
- Comfortable working with ambiguity.
- Able to select appropriate methodologies to manage the project.
- Able to view issues from multiple perspectives.
- Allowed creative thinking and problem solving.
- Treated the project as smaller more manageable projects.

**Executive Sponsor** Typically project sponsors can be treated as purely responsible for the projects finance, however additional responsibilities to the role have been suggested (Remington & Pollack 2007).

- Focus on high level issues and inform the project manager of any issues that have or may arise.

- Establish communication channels for the project manager to follow.
- Advocate for the project.
- Allow key resources to be procured easily.
- Motivate the project team.
- Provide objective criticism to the project team.
- Approve finance.



**Table 2.** PRINCE2 Governance Delegations

Level	Responsibility	Examples of delegating authority using tolerances
Corporate or programme management level	Those responsible for commissioning the project.	Corporate or programme management sits outside the project but sets the targets (and tolerance levels) for the project. The three levels of management within the project direct, manage and deliver within these tolerances and escalate any forecast breaches of project tolerance (Murray 2009).
Directing level	Those responsible for setting direction.	The Project Board has overall control at a project level, as long as forecasts remain within project tolerance, and will allocate tolerances for each management stage to the Project Manager. The Project Board has the ability to review progress and decide whether to continue, change or stop the project. During execution of the Project Plan, if any forecasts indicate that the project is likely to exceed the agreed project tolerances, then the deviation should be referred to corporate or programme management by the Project Board in order to get a decision on corrective action (Murray 2009).
Managing level	Those responsible for the day-to-day management of the project.	The Project Manager has day-to-day control for a management stage within the tolerance limits laid down by the Project Board. During execution of a Stage Plan, if any forecasts indicate that the stage is likely to exceed the agreed stage tolerances, then the deviation should be referred to the Project Board by the Project Manager in order to get a decision on corrective action (Murray 2009).
Delivering level	Those responsible for producing the projects deliverables (products).	The Team Manager has control for a Work Package, but only within the Work Package tolerances agreed with the Project Manager. During execution of the Work Package, if any forecasts indicate that it is likely that the agreed tolerances will be exceeded, then the deviation should be referred to the Project Manager by the Team Manager in order to get a decision on corrective action (Murray 2009).

### 4.2.3 Collaborative Project Structures

Collaborative project structures are one suggested method of complex project governance. The three main principles for collaboration to achieve project success are “organisational structures that facilitate collaboration, attitudes that underpin collaboration, and processes, routines and means to reinforce behaviors, which are supported by the organisational structures.” (Bear 2015)

Organisational structures	Attitudes that underpin collaboration	Processes, routines and means to reinforce behaviours
<ul style="list-style-type: none"> <li>• Motivation and context to collaborate</li> <li>• A joint governance structure</li> <li>• Integrated risk mitigation strategy</li> <li>• A joint communication strategy</li> <li>• Substantial co-location</li> </ul>	<ul style="list-style-type: none"> <li>• The degree of an authentic leadership style</li> <li>• A balance between trust and control</li> <li>• A commitment to be innovative</li> <li>• A common best for project mind set</li> <li>• A no-blame culture</li> </ul>	<ul style="list-style-type: none"> <li>• Consensus decision making between teams</li> <li>• A focus on learning and continuous improvement</li> <li>• Incentive arrangements</li> <li>• Pragmatic learning in action</li> <li>• Transparency and open-book processes</li> <li>• Mutual dependence and accountability</li> </ul>

**Figure 7.** Principles for Collaboration (retrieved from Mastering Complex Projects)

In collaborative structures the set of shared values and commitment to common project goals can create close project teams. Basing the goals and values on project performance criteria can assist in team selection, induction and training. (Bear 2015) Human resources are critical for a projects success and the right people need to be retained. Because of the teams need to function it may be better to reassign tasks than to fill a vacancy with an unsuitable candidate. (Bear 2015)

Some key differences to traditional structuring are “breaking down traditional silos by basing team structure on tasks, rather than specialisation or function, co-locating the core project team where possible, or implementing measures to allow formation of virtual teams with frequent communication and interaction, designing induction training to reinforce shared values and pass them on to new team members, empowering team members to challenge accepted procedures and norms to achieve excellence, involving project owners and external stakeholders in face-to-face meetings with the project team, implementing incentives that reward achievement above ‘business as usual’ these can be financial where appropriate, but can also be recognition based for team members.” (Bear 2015)

For complex projects to succeed the project manager needs to ensure the project clearly aligns with strategic and policy objectives in order to maximise value to investors, and stakeholders while implementing the project in a responsible manner. As projects become complex and the teams confidence wanes the chance of success also lowers. (Remington 2011) By accepting the need for creative or innovative thinking in complex projects and in team selection over best practice. The push for creativity and innovation in complex projects allows engineers to exceed performance criteria and set new standards. (Bear 2015)

**1.1** System Product

**1.2** System Support

**1.3** System Testing

**1.4** Project Management

**1.5** Systems Engineering

#### **4.2.4 Work Breakdown Structures**

A work breakdown structure is used to identify essential tasks to assist in scheduling, costing, and planning. The work breakdown structure defines all tasks the project needs to accomplish in a hierarchal structure. As more about a project becomes known, the WBS should become more detailed as tasks are identified.

The following are a suggested systems engineering approach to a general structure for the WBS (Kossiakoff et al. 2011):

From each heading, there may be subsystems, components of those subsystems, breakdown of tasks within component. Not all subsystems and components will go to the same level, and the WBS should go to the level at which program control, detailed specifications, interfaces, and work assignments are available (Kossiakoff et al. 2011). The WBS can have as many different levels as appropriate.

Once a detailed WBS has been produced, cost controls and estimating can be efficiently applied. Each work package can have a budget allocated and from project initiation each cost is distributed between work packages. From these allocations cost controls can be effectively used by analysing actuals against estimated costs. When these values deviate outside of a certain threshold, the governance structure may be required for approvals or project changes may be necessary. By capturing these costs organisations can more accurately estimate future projects more accurately than comparing entire work packages (Kossiakoff et al. 2011).

#### **4.2.5 Earned Value**

Earned value performance measurement (EVPM) is used to measure and report on a projects performance, combining the estimated costs and the schedule. (Australian Standards 2006). Unlike the usual project tools, EVPM examines the project as a whole.

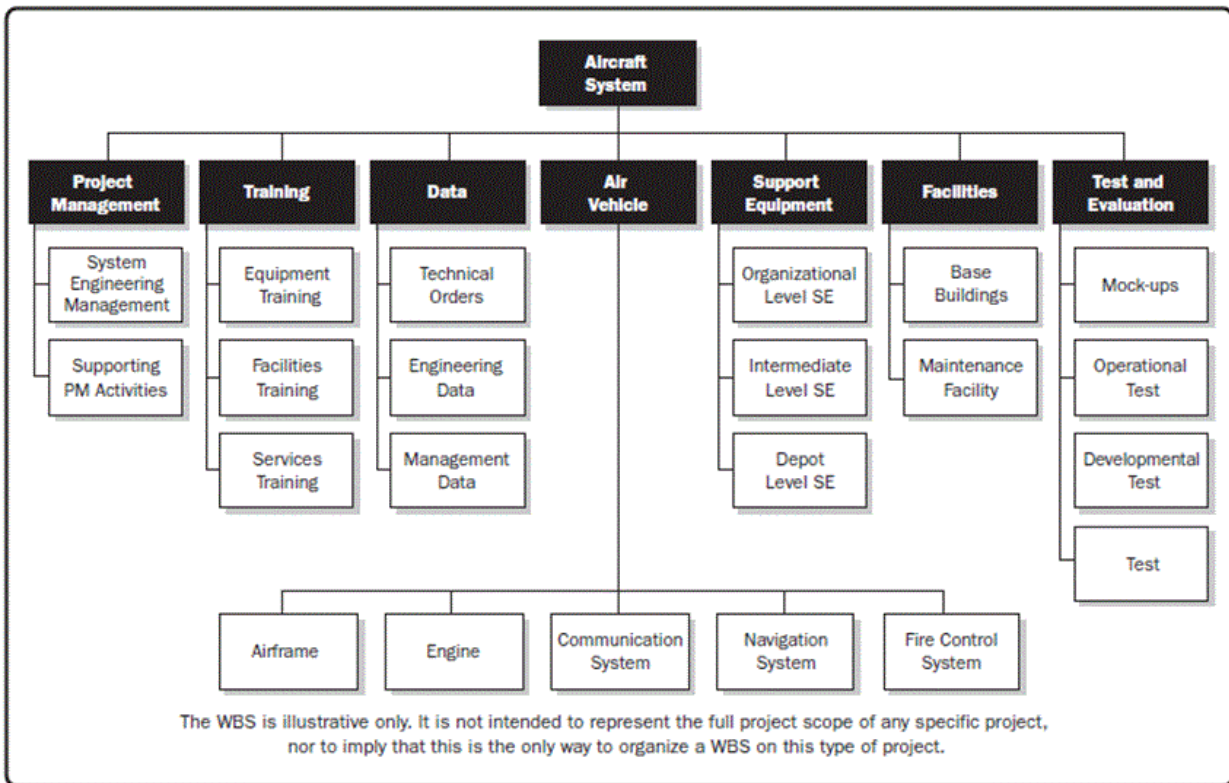


Figure 8. Example Work Breakdown Structure (reprinted from PMBoK)

The following terms form the basis for earned value.(Australian Standards 2006)

**Actual Cost (AV)** The actual costs incurred for works completed to date.

**Earned Value (EV)** The value of the work completed. The earned value will always be equal to the budgeted amount for completed work.

**Budget** The amount budgeted for completion of the activity.

**Budget at Completion (BAC)** The total budget for an activity, work package, entire project, etc.

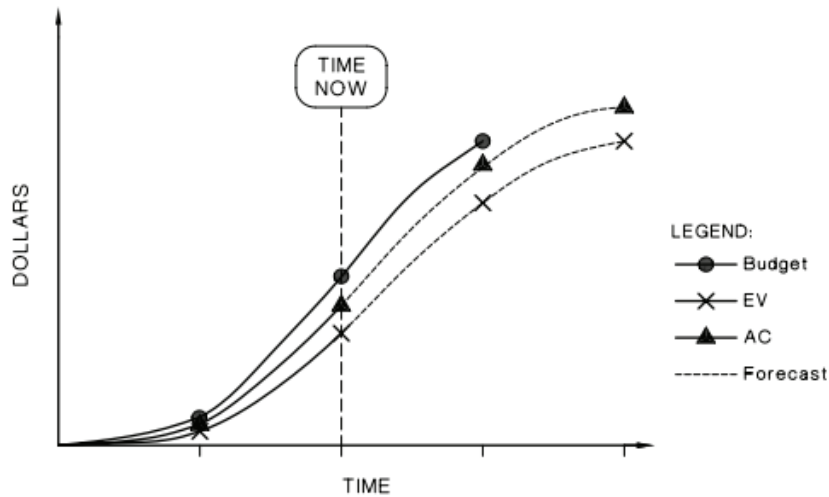
**Cost Variance (CV)** The difference between the earned value and actual cost.

**Estimate to Completion (ETC)** The expected additional cost to complete an activity, based on the projects performance to date and anticipated budget.

**Estimate at Completion (EAC)** The expected total cost of an activity. The sum of the Estimate to Complete and the Actual Cost.

**Planned Value (PV)** The sum of the budget for work scheduled to be completed.

**Schedule Variance (SV)** A review metric, the difference between the Earned Value and the Planned Value.



**Figure 9.** Example of Earned Value (retrieved from AS 4817 - 2006)

The earned value measure requires objective performance measures to allow analysis. The performance measures are used to express the earned value of sub-tasks, and should allow consistent measurement with only one measure per activity (Australian Standards 2006).

Once the earned value has been implemented, the project manager or project governance can begin to introduce project controls and approvals for corrective action. A commonly used index is the Schedule Performance Index (SPI):  $SPI = EV/PV$ . An SPI greater than

1 means the project is ahead of schedule, and less than 1 the activity is behind(Kossiakoff et al. 2011).

The second commonly used index is the Cost Performance Index (CPI):  $CPI = EV/AV$ . A CPI greater than 1 means the activity is over budget, and less than 1 the activity is under budget (Kossiakoff et al. 2011).

Earned value integrates a projects scope of work with schedule and cost elements to allow for efficient project planning and control (Kwak & Anbari 2012) NASA Earned value management provides improvements for not just contractor work, but also internal work. EVM allows timely and accurate analysis of a projects progress on individual WBS deliverables for early detection and mitigation of issues that begin to arise within the project. Effective EVM will incorporate the projects Risk Management with consideration for scheduling and costs of risks, where estimating the risks may be too difficult the projects contingencies can capture them.(Kwak & Anbari 2012)

The combination of cost and schedule into value allows a practical method to measure a projects progress, four examples commonly used for EVM are:

The project is ahead of schedule and under budget No controls necessary

The project is ahead of schedule and over budget. The project can have the works slowed to return to budget, or the early completion may mean a consistent cost with the completed budget totals and the decision may be to proceed at the current rate.

The project is behind schedule and under budget. The project may require additional spending to get back on to the projects baseline schedule.

The project is behind schedule and over budget. The project may need to have a reduction in scope delivered.

The implementation of Earned Value Management requires additional rigor in establishing the project initially, however the increased control over large projects justifies those constraints. The additional work required to manage EVM makes it impractical to implement for smaller projects.For the projects initiation phase an initial WBS, Integrated Baseline Review, Baseline Project Plan.

The WBS developed for the purposes of EVM needs to be focused on deliverables and capture as many levels of WBS as practical. The schedule requirements establish the scheduling baseline from which other schedules may be developed.

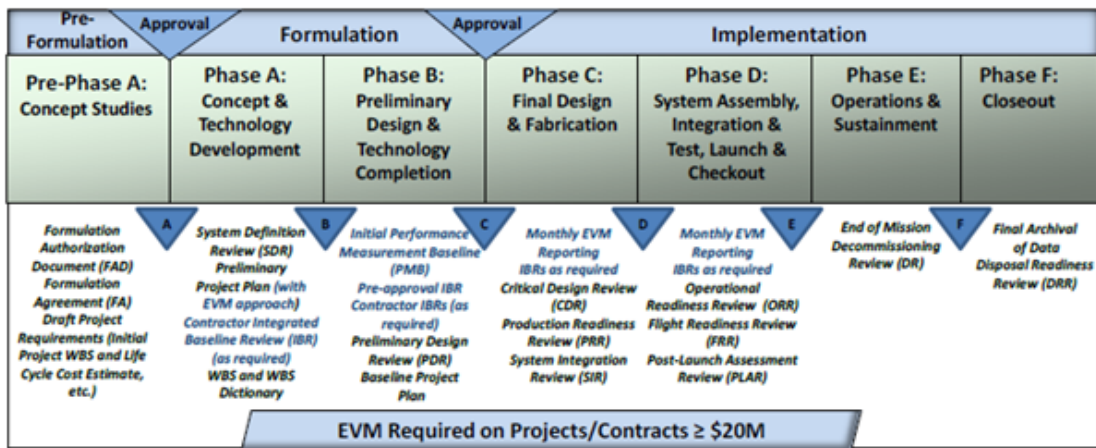


Figure 10. NASA Earned Value Management Process

#### 4.2.6 Risk Controls

Risk management must be an integral part of project initiation. Risks to a project's financial viability, scheduling, improving public perception, reliability or failing to meet the agreed scope must be identified. Different project stakeholders may be interested in different project risks. After key risks have been identified the risk controls must be considered. Risk controls may include transferring risks through contractual arrangements, thresholds for controls, contingencies and other management plans. (Bear 2015)

Complex projects require sufficient resource allocation for the evaluation and identification of critical risks. Allowing sufficient time for risk management can reduce the chance of project failure. The process needs to carry through from initiation to completion and treatment of risk must embed all decisions of the project.

A common method of risk management is to share the risk through partnerships. Some countries have begun promoting alternative procurement methods for dealing with public infrastructure projects (Shen, Platten & Deng 2006). The public private partnerships are intended to improve the efficiency of management by incorporating the private sector. A typical public private partnership will include the operation of the facility. The partnerships offer the benefits of accelerating the delivery of the projects, encouraging more efficient project delivery, reducing the whole life costs incurred by including operation and maintenance of the project as a responsibility of the private sector creates an incentive for the design to minimise ongoing costs, the risks are allocated to the organisation that will be most able to manage the risks and ensuring performance through ongoing payment (Delmon 2009).

AS/NZS ISO 31000 is based on analysing the likelihood and consequences of risks rather than whether or not they are critical to project success. Complex projects require early identification of show stoppers no matter how unlikely. Project leaders have a legal obligation to ensure clear treatments are provided to personnel responsible for risk mitigation and critical risks are dealt with at project start.

A common method of risk identification is holding 'Risk Workshops'. Due to the risk of group think an effective approach is to encourage creative thinking. The divergent/convergent thinking model is an example of the thinking model. Identified risks are presented as "What if.." and controls are presented as "Can we..". Convergent thinking is a logical convergence on a single decision, and divergent is creative thinking with many possibilities. Risk management requires both to succeed. We are often conditioned to think logically but creative thinking is required. (Bear 2015)

Critical risks may be known to a stakeholder but not communicated, these are titled "unknown knowns". Complex projects must manage risks, uncertainty, and ambiguity. A collaborative approach to the project can allow resolution of ambiguities, uncertainties and better inform the team.

Once risks are identified, treatments are required. AS/NZS ISO 31000's standard risk



treatment is “retaining and managing the risk, avoiding the risk, transferring the risk to another party by contract.” If risks are contracted out despite the affect on collaboration, the risk management process should inform the best placed party to manage the risk.

After planning for all the identified risks, unknown unknowns are still a possibility to derail complex projects. A top down functional vulnerability analysis to identify critical success factors and threats for project failure, continue vulnerability analysis throughout the project, seek threats and incorrect assumptions out rather than ignoring them, use external experts to provide advice with adequate provisions.(Bear 2015)

Cost estimations of risk control should be generous. If a high risk information technology cannot withstand a 400% budget overrun, it should not commence.(Flyvbjerg & Budzier 2011)

At every step of a project, unpredictable outcomes can occur that may pose a risk to the projects success. Systems engineering approaches risk through the System Life Cycle. The life cycle recognises that risk decreases throughout a project as the uncertainty is reduced. The life cycle acknowledges the importance that it is critical to a project for adequate scoping to occur at initiation. New technologies also add to a projects risk as it can be difficult to ensure they meet the performance criteria(Kossiakoff et al. 2011).

Risk management is a major component of the Systems Engineering Management Plan. Systems Engineering approaches risks with the view of eliminating alternative solutions that are based on uncertain or ambitious but unwarranted solutions that are unsuitable to addressing project goals.

Each component of a design will have a risk assessment performed to ensure proposed features with a significant program impact are identified. By approaching risks in this manner, the projects uncertainty can be reduced and design changes can be performed with the least financial impact (Kossiakoff et al. 2011). When risks are identified, further testing and analysis may also occur to eliminate weaknesses or potential issues. The assessment serves to identify where resources are needed to be spent.

A rough estimation of uncertain technologies assists in quantifying risks, this may occur by examining where the technology has already been used in a similar function, or determining the technologies development. It is usually adequate to assess uncertain technology to three levels of either high, medium, or low risk (Kossiakoff et al. 2011). By focusing on immature or complex technologies the project can reduce uncertainty. If too many are identified, the project may be too ambitious and need further consideration (Kossiakoff et al. 2011).

Risks are a combination of likelihood, and impact. Assigning agreed values to project levels eg. “High Impact: Major degradation in performance (50-90%)” can assist in analysing components. Systems engineering typically doesn’t provide a single numerical value of risk, as it can appear to be a quantitative value with no basis, and diminishes the informational content(Kossiakoff et al. 2011).

The following is a summary of the risk mitigation process outlined in (Kossiakoff et al. 2011).

**Technical and Management Reviews** Formal design review generally of components forecast to have the greatest impact. The systems engineer must ensure that significant risks are discussed so management and resources may be directed to issues.

**Oversight of Designated Component Engineering** Assign status to each designated problem area subject to frequent reviews, may require external consultants to be engaged.

**Special Analysis and Testing** Where design issues are not resolved in initiation, additional testing and if required fabrication may be carried out to provide additional design data. This requires additional resources and a modified schedule.

**Rapid Prototyping** Where components are unproven, prototyping may be required to validate design. If the issue is not identified in the initiation, and when it isn't, the rapid prototyping may be necessary.

**Relief of Excessive Requirements** The initial scoping and project goals may not be practical and adjustment of goals may be necessary. The result should be practical and consider performance, cost, and schedule.

**Fallback Alternatives** Alternative design solutions for new technology should be established during initiation and almost always result in reduced performance, increased cost, or another deficient but are more conservative than the chosen solution.

#### **4.2.7 Shaping**

The Mastering Complex Projects white paper identified an additional governance role for complex projects. A Project Shaper to be involved with the project from initiation and assist the business leaders in 'shaping' the project to ensure success.

The skills and knowledge of the people filling key governance rolls can help move a project from a complex one to a complicated one (Bear 2015). By appropriately capturing the lessons the project team has learned from completed projects allows the entire organisation to benefit from not just project successes, but also failures.

The organisation should provide resources for the project team to reflect on and document the lessons and possible solutions for the future. By having well-developed processes and practices the organisation can promote learning, encourage role models and support project teams. (Bear 2015) Suggested that professional associations could be a key to increasing transparency between private and public organisations. Currently lessons learned may not be transferred between organisations due to a fear of an impact on share prices, embarrassment, and confidentiality. For that to succeed upper level management must actively support employees participation and acknowledge the value that can be found with improving their projects outcomes.

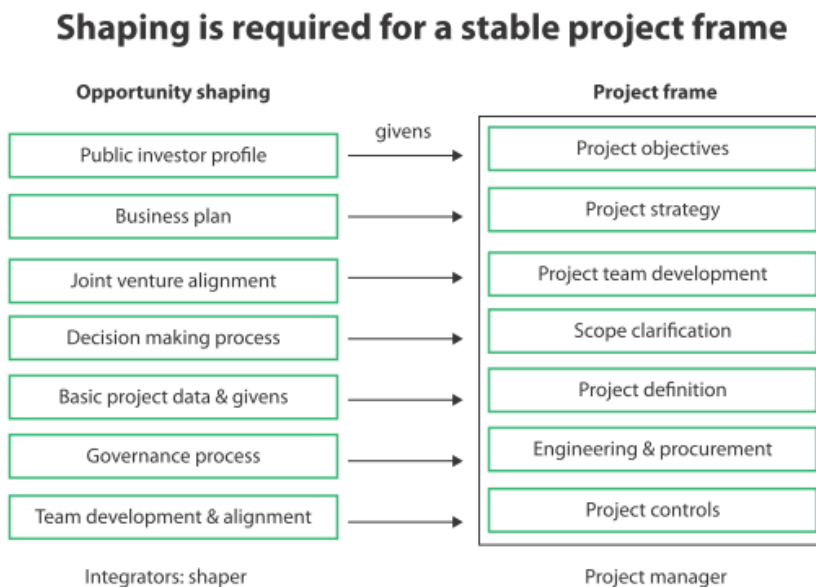
Collaboration and communication is essential. Because during the shaping stage the project team is not formed, the main function is to consult with stakeholders to reach an agreement

on project scope and feasibility. Open collaboration to facilitate understanding can reduce different opinions on when a project is successful and any future scope creep. By engaging the internal and external stakeholders appropriately the project success definition can be established and used for performance criteria and strategic goals.

Project stakeholders must adhere to the following values. (Bear 2015)

- confidence to offer views about the project and accept the views of others
- time, space and tools for collaboration provided by leadership or project initiators
- a common understanding by all interested parties that they need to share ideas and knowledge to obtain the best solutions for the project.

The political environment of the project can be a large source of project complexity. Environmental impact, noise and congestion, indigenous and cultural heritage, lack of infrastructure, and the difficulty of attracting a skilled workforce to a remote site may greatly increase the complexity of implementation for technically straightforward projects (Bear 2015). Political issues can lead to project failure or even termination before completion. The stakeholder engagement is a responsibility of the project shaper. Approving any major changes, supporting the project manager, conflict resolution, mediation with stakeholders, and high-level decisions on behalf of the initiating organisation. By proving the project shaper with delegated authority to effectively engage with stakeholders (Bear 2015).



**Figure 11.** Role of Project Shaping (retried from Bear 2015)

Shaping the projects personnels attitudes is can provide resilience to a project. By approaching tasks in realistic, objective manners. An organisational culture that focuses on the importance of project completion documentation can assist in managing ambiguity and uncertainty. Conditional factors refer to the projects conditions. Clearly defining the

projects mission, consistent reporting and formal decision structures, and project control systems. The shaper should try not to delegate too much of the positions responsibilities to the project manager. The coordination of stakeholders is crucial for project success. The shaper should be competent with project management to ensure they are capable of understanding their role and making educated decisions (Bear 2015).

The enthusiasm of project stakeholders must be tempered to create realistic expectations. The projects budget, scope, and schedule must be realistic to minimize the chance of project failure (Bear 2015).

#### **4.2.8 Effective Leadership**

Effective leadership relies on more than having tools in place to manage projects. Effective leadership needs an establishment of trust for cooperative relationships to succeed. Project teams can have personality clashes, the difficulties of projects can impact team morale, and conflicts can arise. Effective leadership requires innovation and flexibility in dealing with unforeseen project issues (Larson & Gray 2011).

The leadership requirements of smaller projects may be very little, but as projects begin to become 'complex projects'. The leadership required within complex projects can be massive, and additional thought as to who the right choice for the specific project is. The leadership choice needs to be someone capable of both managing the projects resources, and leading the projects team.

It is easy for project managers to take a hands on approach, micromanaging the individual work activities. Micromanagement can lead to heavy-fisted leadership and adversarial relationships between contractors and management.

The reputation of the project manager is critical to their leadership, and it is important that the project manager takes responsibility for their actions and builds respect and cooperation between their stakeholders (Larson & Gray 2011).

The following qualities have been identified as important qualities of an effective project leader (Larson & Gray 2011):

**Innovative** The project manager needs to encourage innovative solutions to problems and balance the requirements of the project schedules with the needs for innovation.

**Capable of viewing the big picture** The project manager must be capable of examining projects from a high level perspective.

**Encourage individuals but push teams** Pressure can be applied to teams and keep up motivation and drive, however the individual team members need to be treated with respect, and the requirements of each person and what can drive them to succeed varies. It is important that the project manager recognises these differences and treats them appropriately.

**Awareness of leadership needs** Some tasks may require the project manager to be in the field managing them directly to ensure the projects succeed, and it is important that the project manager can recognise when a task requires their direct attention and when they require very little.

**Flexible but ensure the project remains on task** Throughout the project it is likely tasks may run ahead or behind schedule. It is not very common for every task of a project to remain on schedule and on budget. The responses to these schedule variations must be tempered and consideration given to what the appropriate responses may be.

**Cultivate tight-knit teams** Project teams need to have cooperation and comradery fostered. It is important that the project teams also maintain perspective of their position with the wider organisation.

### 4.3 Uncertainty

Uncertainty is a major source of complexity, and it requires early identification of when the path or destination of the project is no longer clear. It can occur when information is lacking or inadequate, details are ambiguous, complicated or unpredictable (Brashers 2001) it has also been found that project members doubting their personal knowledge or the knowledge of their field on the subject can greatly impact the projects uncertainty. A projects lack of certainty will also lead to issues of trust with personnel lacking confidence in the team and their leadership. (Geraldi & Adlbrecht 2007)

#### 4.3.1 Stanislavsky's Method

Technically or directionally complex projects often require innovative thinking to assist with solving the problem. To ensure stakeholders and project team members have a sufficient technical knowledge to think about solutions to problems that may not be in their typical expertise, Stanislavsky's Method involves the person thinking about the project in a different way to their usual approach (Remington & Pollack 2007). The team member may think of problems as structural, and instead consider the problem organizationally. By viewing the issue from a different perspective it is possible to see the problem from a more appropriate one. Possible perspectives that can be employed include(Remington & Pollack 2007):

**Complexity** The perspective may be temporal, directional, structural, or technical.

**Economic Focus** View the problem from a financial perspective.

**Information Systems** Look at how the solutions data flows and is interpreted.

**Structuralist** Understand the structure of the organisation and its operations.

**Functionalist** Look at the issue as a function that is performed by a system.

**Mechanistic** View the issue as a machine to be engineered.

**Organic** View the issue as an interconnected organic organism.

**Interpretive** Examine the influence of interpretation in reality.

By thinking about the issue in a different way, they can be prompted to develop a deeper understanding of the topic. The development of these different perspectives can take time, but through learning the perspective the ability to reframe the problem can allow innovative thinking and problem solving.

### **4.3.2 Project Scoping**

Clearly defining success criteria that is aligned with unique performance measures based on stakeholder views. The criteria may be qualitative, quantitative, long or short term. (Bear 2015) Defining performance objectives early in the project execution allows earlier decisions on terminating or reshaping a project with the lowest financial impact.

A major challenge for complex projects is defining success criteria. In volatile, unpredictable environments it can be difficult to anticipate how criteria may change. It is essential that the governance structure is flexible enough to adapt. (Remington 2011)

The project success criteria can motivate the project team to achieve the client's definition of success. With a collaborative team model allows rewards to be awarded based on key result area's (KRA). By encouraging creative, collaborative thinking they can form a basis of the project teams values and culture.

Engineers in charge of the change process can allow project teams to identify and implement needed solutions. Through collaborative tools an engineer can ensure the projects focus remains on the performance criteria. By basing technical processes on the criteria and identifying required changes as early as possible the projects can remain on task.

The traditional adversarial relationship between the project management team and clients caused by contractual terms and risk sharing leads to increased budget issues. Scope creep due to a failure of project definition is often an issue of the relationship. The project manager extending a culture of collaboration to contractors or joint venture partners by avoiding punitive contracts and risk transfer. Involving external consultants or contractors in training sessions, informal progress meetings, launches, including elements of project culture, incentives or recognition in contracts of achievements, and educating those responsible for procurement on contractor entitlements to avoid pay disputes.

### **4.3.3 Project Controls**

Project controls require the collection of data to allow reporting and minimising risks. Typical data collected includes earned value, cost, schedule progress, work hours or other inputs, outputs, and identified risks. Implementing thresholds assists in governance, risk management, budget, scheduling etc(Larson & Gray 2011). Performing analysis with scheduling tools allows informed decisions to be made.

Suggested complex project controls include targeted, meaningful metrics, a common work breakdown structure and cost breakdown structure, clearly defined critical and interface milestones, committed budgets, costs and forecasts, actual costs against earned value, quantities tracking feeding objective progress and cost measures, risk valuation, change management, reporting on key performance indicators, provide data to allow emerging risks to be managed or identified(Larson & Gray 2011).

The project controls allow the project manager to treat risks before they become bigger issues while maintaining contingencies. Forecasting of risks with predictive modeling like the Monte Carlo method of integrated cost and schedule risk analysis is often used for this(Larson & Gray 2011). The Monte Carlo simulation method analyses 1000 trials of simulation based on the best-case, expected, and worst-case data, similar to a PERT distribution or triangular distribution.

The simulation's central estimate will typically be close to standard analysis, however the best and worst cases will be lower than their absolute values. This is more realistic because should one task take the worst case time it doesn't mean all other tasks will. The scheduler can select a threshold for example 75% and find the time the project will be completed on or before a certain duration(Larson & Gray 2011).

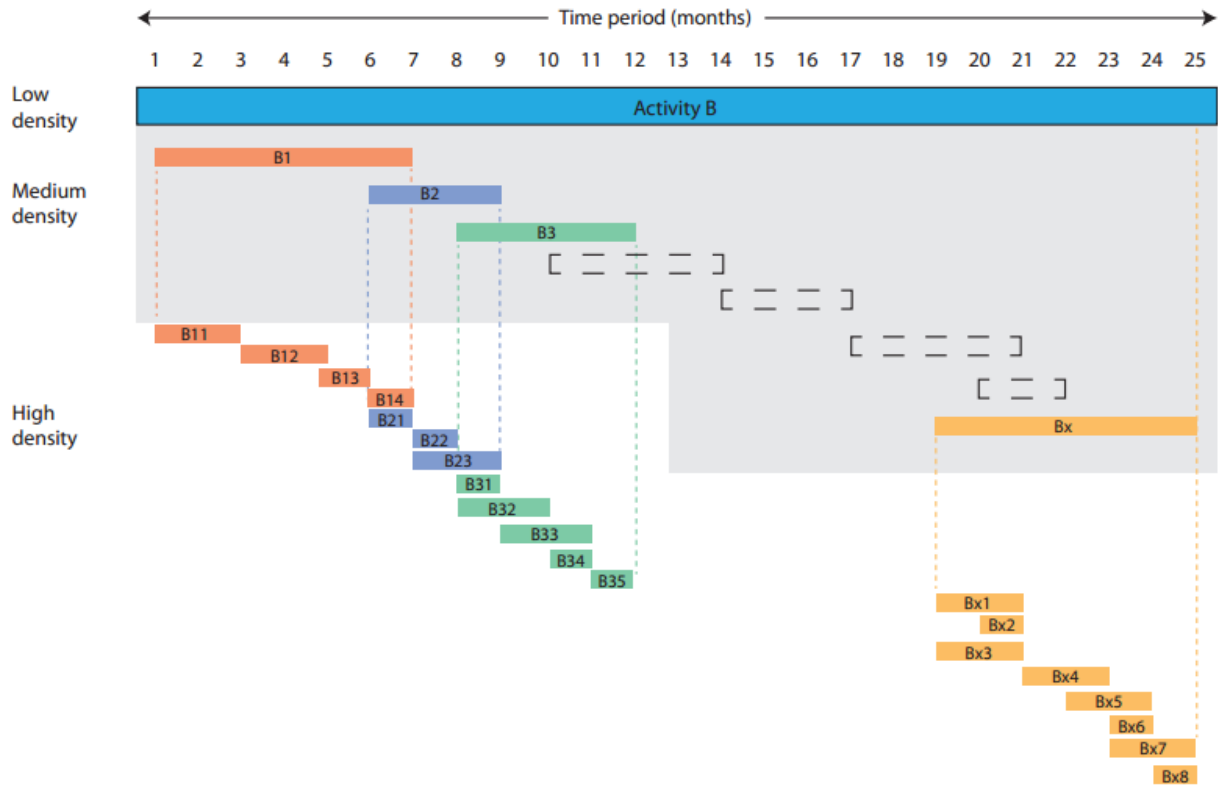
### **4.3.4 Scheduling**

Scheduling is a statement of intent. (Bear 2015) The scheduling is based on experience and educated estimates but cannot be developed with certainty. This can lead to overruns and disputes over contract delays. By going into too much detail can create difficulties in progressively updating them as project conditions change.

For complex projects, the schedule density method can be used. (Bear 2015) Schedule density is the production of a schedule is based on the projects method statement and to whatever level of detail is required to manage the project. The medium density schedule can then be used to identify milestones of the project and help to identify possible scheduling conflicts. The schedule must be realistic and attainable for the project with adequate resources allocated to the creation and maintenance of the schedule. (Bear 2015)

For scheduling consider where control points can be implemented, typically these will be around the project milestones. The control points are stop points for the project where approvals for another stage of works begin (Murray et al. 2009). The milestones can also

provide a point for governance to assess how the project is progressing and can be a good time to report. Resources are also applied during scheduling and some smoothing may be necessary to reduce peak resourcing issues. The scheduling and resourcing produced can then be used to produce more accurate costings.



**Figure 12.** Schedule Density Concept (retrieved from Mastering Complex Projects)

#### 4.3.5 Independent Assurance

Independent project assurance is a form of project oversight that is intended to provide a more objective review of project forecasting and benefits (Flyvbjerg 2013). Work conducted to review decision making processes made in uncertain circumstances is often caused by the “planning fallacy” (Kahneman 1994) resulting in underestimation of project costs, scheduling, and risks, and overestimate the benefits.

The suggested method for reducing the impact of the planning fallacy is the inclusion of an external view of the planned actions. The estimating should instead be performed using realistic past project performance (Flyvbjerg 2013). Inaccurate forecasting can damage project trust and create conflict on project delivery.

Separating the project assurance from the project manager allows for quality assurance of the project processes. The project assurance, as the name implies, should not be fulfilled by



a member of the project team, or another project manager to ensure a truly independent analysis is possible (Flyvbjerg 2006).

#### **4.3.6 Top-Down Approach**

Top-Down project scheduling estimates are performed to evaluate a projects proposal. It may be necessary to provide scheduling estimates before the creation of a detailed scoping document or the Work-Breakdown Structure. The top-down approach can be performed by experienced managers in either a workshop or through the Delphi Method. Top-down estimating should be used to inform decisions on where further project planning may be necessary. Rigor needs to be incorporated where possible to prevent the risk of “sacred cow” projects and to ensure the scheduling and costing is provided as accurately as practical.

#### **4.3.7 Apportion Methods**

The apportion methodology is an extension of the Ratio Method and Top-Down Approach to project scheduling and cost estimates. Apportion is the method of using past projects that delivered similar outcomes (Larson & Gray 2011). The method isn’t massively accurate, but it allows for quick, resource light estimations. From the apportionment project deliverables are assigned a percentage of the total project cost for progress claims to be made (Larson & Gray 2011).

#### **4.3.8 Contractual Arrangements**

For large infrastructure projects there may be public private partnerships (PPP), joint ventures, or international partnerships and the differences in organisational culture can play a large role in the foundation of trust, motivation and procurement processes. The difficulty of traditional governance structures being applied to these cases can create many issues. It is important that the governance represents the culture of all involved parties.(Börzel & Risse 2005)

Contractual relationships can also cause issues, with traditional contracts leading to adversarial relationships. The importance of guiding these relationships through alterations to the contract structure and distribution of risk the relationship can become focused on the success of the project, rather than the parties trying to extract the most they can from each other.

## **4.4 Technological Uncertainty**

Technically complex projects are those which have unknown or untested design aspects. There will be no prior examples of the work although there may be similar aspects of other projects that could assist in informing decision making (Remington & Pollack 2007). The complexity can make it difficult for the management team to be aware of the design teams actions.

The power granted to the design team can create difficulties in managing time-lines Technically complex projects may have a plethora of possible solutions due to the difficulty in defining outcomes. The best technique to manage the project is a flat hierarchy (Remington & Pollack 2007) with an informal director. It is important for roles to be clearly defined with naturally forming team structures. Communication will also take place through informal meetings and less structured formal communications. If groups operate autonomously it is important for the project manager to ensure that the projects direction is unified.

### **4.4.1 Bottom-Up Approach**

The bottom-up approach, unlike the top-down approach, estimates the project costs from previously completed project works. The differences from the past project to the new one can be accounted for and scheduling and costings can be adjusted to apply to the new project (Larson & Gray 2011). This has an obvious issue when approaching complex projects that may have difficulty in defining the projects activities early on.

### **4.4.2 Time-Linked Semi-Structures**

The structure for time-linked semi-structures is based on improvisation of Jazz. Jazz is guided by a non-negotiable framework that allows the musician to play fluidly (Remington & Pollack 2007). The process is an analogue for the way complex projects can be managed, by providing a rigid framework that allows flexibility of where they're applied.

This can be provided with explicit roles and responsibilities, high levels of communication, and proactive exploration of future activities (Remington & Pollack 2007). The research suggested that the more rigid the processes, the less successful the organisations, due to slowed innovation and delivery times (Remington & Pollack 2007).

When beginning to plan the project the structure suggests that the decomposition techniques used, work-breakdown structures and precedence networks should be a mix of chaos and order to encourage innovation. The semi-structure involves setting milestones, roles and responsibilities, and regular meetings and communication (Remington & Pollack 2007). The planning should be updated throughout the project, however the recommended procedure for the planning is to produce key milestones rather than detailed time schedules as it is too difficult to predict the schedule of a complex project meaningfully.

The second stage is identifying the resources and roles used for the project with broad responsibilities (Remington & Pollack 2007). Recurring meeting dates also need to be communicated to those expected to attend. The general agenda should be to track the progress and attempt to solve any problems that have arisen. The meetings shouldn't act as micromanagement of teams but control the general steering and expectations for the next meetings. The initial chaos experienced by the project should develop into the expected alignment as it approaches the deadline and solutions are agreed upon (Remington & Pollack 2007).

#### **4.4.3 Project Oversight**

Project oversight has been defined as 'a set of principles and processes to guide and improve the management of projects' (Larson & Gray 2011). Oversight of projects will include decisions relating to project selection and approval, portfolio and program management, improvement of processes, reviewing progress, tracking project bottlenecks, review of lessons learned, authorise change requests, and even terminate or defer projects (Larson & Gray 2011). The oversight of projects should help contribute to a more consistent and accountable process.

#### **4.4.4 Roles and Responsibilities**

For effective leadership the right people are critical for fulfilling the right roles and responsibilities. The different levels of leadership should work in synergy with successful communication between them. Sponsorship can be difficult to define in public infrastructure work projects. Key roles should be defined with some redundancy and flexibility to adjust to project needs.

Complex projects need higher skilled leadership and it is important to recognise this. The leadership may need to be capable of self-reflection, communicate with high level connections to prevent adversarial positions, have sufficient power within the organisation, support the project to stakeholders, provide motivation to the team, and be willing to collaborate with teams rather than exert formal authority (Remington 2011).

Redundancy in the leadership roles allows projects to minimise downtime while waiting for approvals or information (Remington 2011). The cost of failure with governance is considerably higher than the cost of additional resourcing. The redundancy for key roles allows safeguards for the loss of project critical positions. The loss may be from illness, accident or poaching.

Successful project leaders can also become over confident, or the organisation may become over-reliant on the person. The performance can set new organisational benchmarks which can often lead to conflicts between teams and the classic Australian 'Tall Poppy' syndrome.

The project leaders should be delegated the power to select their teams personnel. If lead-

ership teams become too large can slow down projects, prevent effective decision making, and cause project uncertainty (Remington 2011). It may also be necessary to replace team members that are found to be unsuitable. Project teams should be resourced as if they are temporary organisations with the project leaders acting as the CEO (Turner & Müller 2003).

Organisations can struggle to hold certain roles accountable. Often employees will point out other people's inadequacies, tell others what they want to hear, omit key details, speak vaguely, divert attention by introducing irrelevant material or focusing on details, avoiding decision points, degrade or embarrass others, or often in projects agree verbally but refuse to sign off (Remington 2011).

If people don't have clearly defined roles or responsibilities it can be difficult for them to know what they are accountable for. The assessment of resources and role definition must be developed simultaneously (Remington 2011). The definition must encourage systemic thinking rather than obfuscation and hiding of information to project leaders or executives.

Complex projects inherently make it difficult to measure cause and effect due to nonlinearity. If accountability cannot be measured at one level, the accountability should move up and view the situation holistically (Remington 2011). Providing transparent assignment of tasks can allow more accountability, linking of accountability to project benefits, induction material for new leaders and team members outlining the roles and responsibilities, clear communication and documentation, a culture of 'no blame, but no excuses', and suitable ways for team members to communicate bad news (Remington 2011).

Systems engineering's approach to roles and responsibilities is called an SEMP, or systems engineering management plan. The SEMP formalises the management of the engineering effort, by informing the team of their responsibilities. The SEMP will sit within a Program Management Plan and should be updated throughout the project (Kossiakoff et al. 2011).

#### **4.4.5 Functional Analysis**

The projects functional analysis should list all requirements for the project. The document can be used to define early specifications of the project and as the project progresses it can form a basis for the project commissioning documentation (Larson & Gray 2011).

### **4.5 Cause and Effect**

As the scale of a project increases and multiple key decisions between stakeholders and the project team occur throughout the project, the project can become 'non-linear' where cyclical chains of events reinforce each other, often caused by technical complicity, unclear decision-making or unexpected environmental changes. The non-linearity of the project makes it difficult to evaluate actual project progress, recognise where resourcing is needed, and respond to issues appropriately. The 'effect' of 'cause and effect' can lead to massive

budget and scheduling overruns, and even failure to solve the projects original need. (Geraldi & Adlbrecht 2007).

#### **4.5.1 Target Out-turn Cost**

Large infrastructure projects have a high rate as failure, as discussed in Chapter 1. Often the failure is due to external influences that the project manager couldn't feasibly control (Remington & Pollack 2007). When minor risks go unnoticed and trigger other minor risks the issue can escalate (Remington & Pollack 2007). The traditional approach to project procurement produces an adversarial rather than collaborative approach to resolution of issues (Bear 2015). The approach suggested is to change the relationship between the principal and the contractors. The collaborative approach combined with traditional project management tools has the benefits of (Remington & Pollack 2007);

- Improved predictability of cost, time and quality;
- Minimised risk;
- Reduced costs;
- All parties enabled in a team environment to make maximum contribution;
- Innovation promoted with additional benefits as to 'best for project' attitude;
- Understanding of other parties' issues;
- Continuous improvement of process as it is in the interest of all parties;
- Development of long-term relationships and highly efficient vendor supply chains;
- Improved trade performance and better scheduling;
- Workarounds to reduce delays when things go wrong;
- Acceptance of an agreed project management approach.

The larger infrastructure projects have added difficulty due to the massive number of activities required in large projects of this scope, and many of the activities may have individual sub-contracts or contracts with interdependencies on each other. Small scheduling issues can compound and force costs and time to become out of control (Remington & Pollack 2007). An approach to collaborative contracts was proposed to reform the relationships produced by traditional contracts(Latham 1994).

The following key points of the approach were identified (Remington & Pollack 2007)

- The organisation operates with a 'no claim, no blame' culture such that the team owns and manages the risks to the best of their ability;

Through better control of scope, joint costs and risk management and the promotion of innovative and ‘best for project’ solutions, all stakeholders benefit;

There should be equitable benefits for all parties in the arrangement;

An attitude of openness and trust is required to make collaborative working stressful;

Encourage team attitude and ‘What is best for the project’;

Ensure adequate time is spent at pre-planning;

Include all the organisations and sub-contractors from as far down the supply chain as possible, as it is they who do the work;

Make long-term arrangements to eliminate the need to start from scratch on each project;

Do not underestimate the cultural shift involved and the time the transition to collaborative projects could take.

The collaborative arrangements are a ‘gain share/pain share’, so all parties involved in the project will share in the result, with there being no win-lose result (Remington & Pollack 2007). Payments should be made on the earned value measure. With careful and collaborative estimation and control of costs defined at initiation(Remington & Pollack 2007).

The collaborative approach requires the highest levels of management of the major partners to be responsible for strategic guidance of the project. A lower level of management then takes on the day-to-day management of the project (Remington & Pollack 2007). The Target Outturn Cost or TOC forms the basis of managing the project.

The TOC will include design costs, costs of setting up and maintaining the collaborative relationship, costs of all works on site, management, overheads, profit margins and contingencies (Remington & Pollack 2007). The established collaborative management structure will be responsible for all cost management and it can be typically expected to require 2-3 months of work to establish the structure and reduce uncertainty of the project (Remington & Pollack 2007).

#### **4.5.2 Systems Engineering**

Systems Engineering is a common approach to complex problems. Systems Engineering views the whole system’s interactions. An example with designing is that it doesn’t concern itself with just engineering design, but also with external constraints. When complex systems require a variety of engineering disciplines, each design element must function properly. These interrelated functions depend on physical and functional interactions and thus cannot be engineered independently. It is in these situations that a systems engineering approach has great value as it can guide and ensure interactions between components function correctly. (Kossiakoff et al. 2011)

### **4.5.3 Critical Path Method**

The schedule that is produced can have detailed start and finish times based on the Monte Carlo Technique, and each event or activity derived from the work breakdown structure can be linked to its predecessors (Kossiakoff et al. 2011). By establishing the longest path to complete the project team can identify the critical path. The links between activities not on the critical path will have 'slack' attributed to them.

### **4.5.4 Decision Gates**

Decision gates are often known as 'Phase Gates', the organisation or governing body may establish a gate at key points of a project. These are similar to Inspection and Test Plan hold points that occur through construction management, however it is specifically for project processes. When a gateway is reached, as outlined in the projects governance, a review of specified project outcomes will occur. The review should include assessments of resourcing, whether the project should continue, and evaluation of the project (Larson & Gray 2011).

Unlike the some other forms of project review, decision gates are designed to be an integrated component of an organisations project management process or frameworks (Larson & Gray 2011). The gateways allow organisations to consider projects as part of their program management structure. Example gateway decisions may include project resourcing, project performance against baselines, are the key performance indicators (KPI) appropriate, is the project appropriately supported, etc (Larson & Gray 2011). The possible review questions can be anything the organisation feels may be appropriate, and ultimately encourages more accountability, through more consistent oversight and rigid reporting requirements.

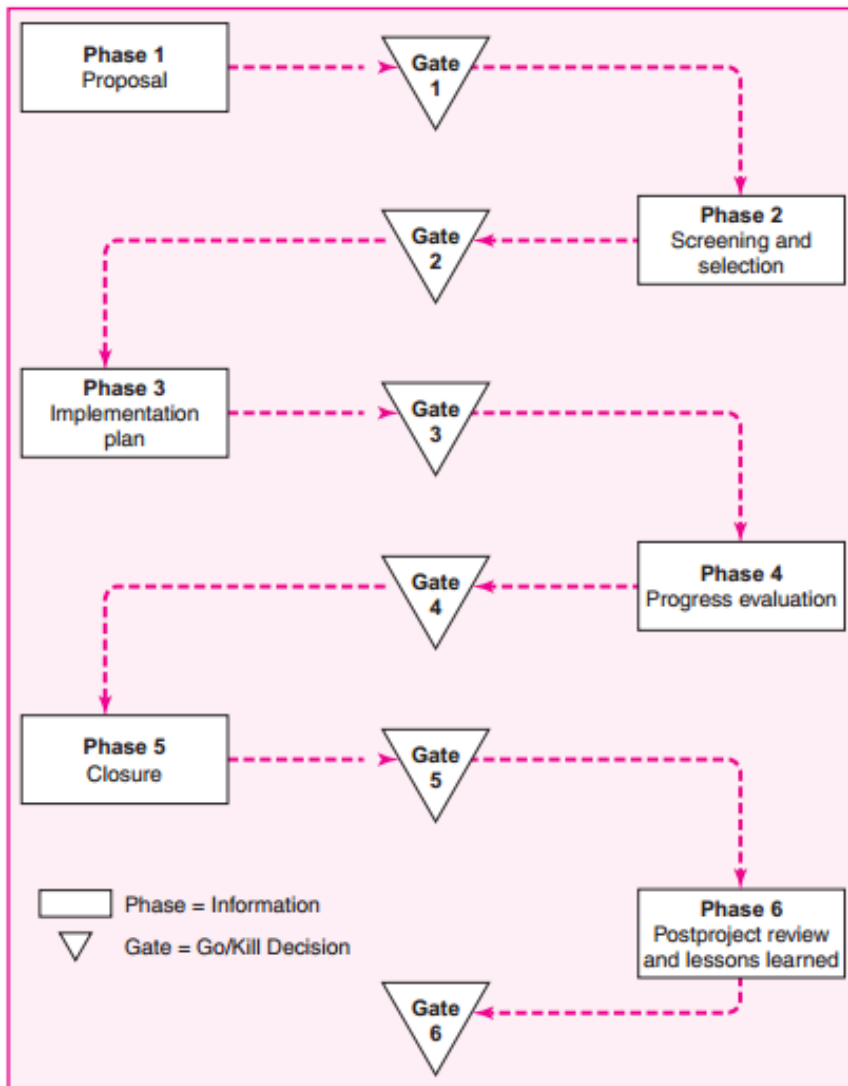


Figure 13. Phase Gate Process Diagram (retrieved from Larson 2011)



#### **4.5.5 Managing Project Teams**

High performance teams are important in many aspects of not just project performance, but performance in all team settings. Important factors in a team success include efficient communication, clearly defined roles and responsibilities, and respect for other team members. Organisational culture plays another massive part of team success, the relationships between team members encouraged by upper management, a culture of blame, sharing of success, and an environment of self-improvement can all contribute positively or negatively to project success (Larson & Gray 2011).

Positive synergy between team members suggested by (Larson & Gray 2011) include:

Common purpose among project team members,

Using individual skills and expertise,

Fair balance of project roles that encourage group cohesion,

Problem solving rather than interpersonal issues,

Encouragement of dissenting opinions,

Encourage creativity and avoid punishment for mistakes,

High personal standards of performance and team encouragement,

Identify with the team and consider it important personally and professionally.

It is important to note that (Bear 2015) considered it important for project teams to not become separate from the organisation and to ensure rotation of members between project teams to reduce the risk of isolation and elitism of successful teams.

## **4.6 Conclusion of Findings**

The project tools and processes identified above can provide immense value to a project, however their application may be difficult. The project tools have been provided with additional qualities that may assist in their usage and implementation. The table of the researched project tools and processes has been compiled to communicate these. The table has been created to inform project managers on the difficulty of implementing the tools, the application of the tools, and the type of project it is.

### **Experience**

- High: Requiring a high amount of project experience means the project manager will generally need to be familiar with the activity to implement it effectively.
- Medium: The project activity will require some experience in its application and additional effort may be needed to effectively implement this.
- Low: A new project manager should be able to implement or follow this activity effectively.

### **Application**

- Broad: The activity may be applied to a broad category of projects.
- Specific: The activity has a specific project type or stage it may be applied to.

### **Type**

- Tool: A tool is an activity that has a specific outcome.
- Process: A process is a set of actions that may be followed.
- Consideration: A consideration is a project activity that project managers should consider in the management of the project.

**Table 3.** Summary of Project Tools Part 1

Tool or Process	Description	Experience Required	Application	Type
<b>General Project Complexity</b>				
Business Case	Provides needs analysis, consideration of project value, and more prior to project initiation.	Low	Broad	Tool
Governance	The management of a project with clear responsibilities, accountability, and expectations.	Medium	Broad	Process
Collaborative Project Structures	A form of project governance that is designed to encourage collaboration between teams.	High	Broad	Process
Work Breakdown Structures	Used to identify project deliverables to assist in scheduling, costing, and planning.	Medium	Broad	Tool
Earned Value	A method of measuring project performance combining scheduling with costs to assist in project reporting and management.	High	Broad	Tool
Risk Controls	Risk management is a legal and moral responsibility of project team members and some tools to assist in this process are	Medium	Broad	Tool
Shaping	A project role dedicated to ongoing management of the projects scope and stakeholder engagement.	Medium	Specific	Process
Effective Leadership	Some considerations for effective project management including flexibility, encouragement, and perspective.	Low	Broad	Consideration
<b>Uncertainty</b>				
Stanislavsky's Method	A thought process that can be used to view issues from different perspectives.	High	Broad	Process
Project Scoping	Clearly defining the project success criteria and scoping requirements.	Medium	Broad	Tool
Project Controls	Methods of project control including Monte Carlo simulation, to provide more realistic project scheduling	Low	Specific	Tool
Scheduling	Development of project scheduling and identifying control points for project approval.	Low	Broad	Process
Independent Assurance	A form of project oversight to provide independent forecasting and benefits analysis of projects.	High	Broad	Process
Top-Down Approach	A method of project scheduling to quickly analyse project feasibility.	Low	Specific	Tool
Apportion Methods	A branch of the top-down method incorporating past project performance in estimations.	Medium	Specific	Tool
Contractual Arrangements	From Public-Private Partnerships to joint ventures, some of the key considerations on project contracting.	High	Broad	Tool

**Table 4.** Summary of Project Tools Part 2

Tool or Process	Description	Experience Required	Application	Type
<b>Technological Uncertainty</b>				
Bottom-Up Approach	A method of scheduling from each individual project deliverable up.	Medium	Broad	Tool
Time-Linked Semi-Structures	The process of establishing project frameworks with rigidity and flexibility.	High	Specific	Process
Project Oversight	Decisions made relating to project approvals and management.	Medium	Broad	Process
Roles and Responsibilities	Critical in all projects, but provide a key function in reducing some of the issues that occur with uncertainty.	Medium	Broad	Process
Functional Analysis	Defining technological requirements serving as a living document throughout the project.	Medium	Specific	Tool
<b>Cause and Effect</b>				
Target Out-turn Cost	A key component of collaborative project structures TOC is a process of establishing a collaborative relationship for the project.	High	Specific	Process
Systems Engineering	Brief summary of systems engineering considerations that can assist in combining project elements.	Medium	Broad	Consideration
Critical Path Method	Forming part of project scheduling, critical paths allow the identification of where additional resourcing may be applied, and where resourcing may be reduced.	Low	Broad	Tool
Decision Gates	Similar to Inspection and Test Plan hold points, these are focussed on project processes and approvals.	High	Broad	Process
Managing Project Teams	Common aspects of successful project teams and organisational requirements.	High	Broad	Process

## **5 Conclusion**

Complex project management requires systems that are capable of providing flexibility to solving problems whilst ensuring enough rigidity to minimize uncertainty and ensure the project team still understands their position, role and the processes they need to follow. The approach to successful complex project management will often require different processes specific to their projects. The recommendations are based on a general approach to what are very complex, individual projects.

One of the most critical components of successful management is in the project initiation and scoping phase. Whilst all phases of a project are important, the scoping must provide information to not just the project team but also to the projects key stakeholders. By ensuring that their expectations or requirements of the project are addressed in the project shaping phase through in-scope and out-of-scope documentation the risk of project creep and failing to address the projects actual goals can be avoided.

The implications of my thesis on complex projects is that there are many existing tools and techniques available for project managers and members of the project management team to follow. I believe that the most critical step in advancing project management and improving project rates of success is an improvement in ongoing professional development and education. Ongoing research into the causes of project failure, and capturing lessons learned from them is of the utmost important for the growth of project management.

It is important that organisations, not just project managers recognize the importance of appropriate governance structures for varied project types. Complex projects are by their very definition, complex. The approach to complex projects cannot be universal, as each one will have its own unique challenges and opportunities. The tools and techniques that have been discussed through my dissertation can be of great value in reducing a projects complexity and helping to provide flexible methods to be followed. Project scoping or shaping is a key area where the complexity of a project can be massively reduced through thoughtful, open implementation of existing techniques. By open communication with the projects key stakeholders the chance of failure due to scope creep, or failing to address the real needs of the projects customers. Providing resourcing to the project to assist in the initial project scoping may be unappealing when it is first considered, as organisations do not typically like to spend additional resources on the provision of new project roles, however the value that can be provided is of immense value to reducing the complexity of a project. Identifying these up front allows the project team to know what they need to be working towards. The reduction in the projects uncertainty provides for a great deal of reduction in project complexity.

Following the shaping of the project the project team can provide the customers, sponsors and key stakeholders with a document capturing all of their individual project goals. The project scoping and ensuring the project is still driven towards the projects goals. Once the scope of the project has been fully agreed on, the project team can begin estimating schedules and budgets. The estimates must be prepared with consideration of past project performance and realistic time frames and expense estimates.

Throughout the project it is important that a governance structure is created that assists all levels of the project team to be aware of exactly what their role, responsibility, and reporting requirements are.

Whether the organisations project management strategy is based directly on existing project management bodies like PRINCE2 or PMBoK, or organizationally specific frameworks, the basic method of getting to the end of a successful project remains relatively the same.

Risk management is a well established, almost cultural aspect of project management. It is not uncommon to attend public forums discussing infrastructure projects occurring in someones local area and to hear the question asked by members of the public “Have you done a risk assessment”. The cultural risk aversion within Australia has some obvious benefits for managing projects, but it is important that the focus isn’t purely on health and safety. While that is obviously a very important component of a risk management plan, other risks must be considered as well. Deep thought with varied perspectives on risks and mitigation techniques is very important for identifying risks TO a project, not just FROM the project. Externalities with potential impacts on projects are important to be identified because leaving them unidentified increases the potential impact from these risks should they eventuate.

Reporting of projects is important not just for whoever is delegated the responsibility of reviewing the projects progress, but also in assisting the project managers to think critically on the projects progress. Many methods can be implemented for project reporting, but one with perhaps the most value is the method of earned value (EV).

The approach I have taken for my research has many limitations that I quickly realized as I began to work in the sphere of project management. The success of a project manager cannot be simply from what has been read through textbooks and journal articles. The project manager, from my own personal experience, requires two other areas to function successfully. They need to have a natural predisposition to the role, with a lot of the human, psychological aspects of when to push on contractors and when to let go forming a very important component of the manager. The third component that is critical to a projects success, is the experience of the project manager. Working in similar projects beforehand, whether it was through the role of project manager or a member of the project team, provides a very important wisdom of exactly where the tools, techniques, and management styles are appropriate. I believe that the project manager will struggle to manage complex projects if they do not have those three components.

As the profession of project management continues to mature, and best practice of project management is refined the failure rates of complex projects may be improved. However due to the growth of project complexity caused by technological uncertainty and scale, project managers must ensure they continue to learn throughout their career and stay current with project management research.

I believe it is also important that the project manager doesn’t get to the point of their career where they believe they are truly above their peers, and that an emphasis is placed on continuous growth of their wisdom and knowledge. No matter how many tools are

developed to guide project management decisions, the very flexibility that those tools require to succeed, places a minimum level of experience required to lead the projects.

## **5.1 Recommendations for Future Work**

For future research I would like to see a refined handbook of project management techniques, tools, and where they can be applied. There are a lot of existing resources for the project managers, but they are often contained in very large volumes, unreadable texts and journal articles. There is a very clear gap in the project management literature for refined, succinct, flexible, and varied tools to be provided for all people involved in projects to view. A collaborative research project between experienced project managers and capturing their experiences to provide these refined tools could prove to be greatly valuable, much like existing Australian Standards for other standards of Australian engineering.

Additional work could be conducted to evaluate more real-world projects. A targeted research project focusing on the capturing of complex project lessons learned within Australia or globally would enable a more refined framework to be established for complex projects. Discovering exactly what was successful on projects and what was unsuccessful could provide great value to the project management profession. The research would likely face a lot of confidentiality issues so it would be quite time consuming gaining access to the data which could pose some serious issues to the project.

Further research could also be directed at contractual arrangements. Forming collaborative project teams can provide immense value to a project however the typical existing arrangements are not conducive to that. An exploration of industry experience with contracts and different structuring could provide for a great improvement in Australia wide project delivery.

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## **A Project Specification**

*University of Southern Queensland*

SCHOOL OF CIVIL ENGINEERING AND SURVEYING

**ENG 4111/4112 Research Project**

**PROJECT SPECIFICATION**

FOR: **Thomas William WAGER**

TOPIC: PLANNING SUPPORT SYSTEMS FOR COMPLEX INFRASTRUCTURE DEVELOPMENT

SUPERVISORS: Dr. Nateque Mahmood

ENROLMENT: ENG4111 – S1, D, 2015  
ENG4112 – S2, D, 2015

PROJECT AIM: This project seeks to examine existing tools and methods used in Complex Project Management and create a logical framework to assist in their implementation.

**PROGRAMME: (Issue B, 10 September 2015)**

1. Research existing Complex Project Management tools and techniques to establish a basis for their implementation.
2. Analyse the various tools and attempt to select Complex Project Management methods that only apply specifically to Civil and Structural Engineering management.
3. Outline existing Complex Project Management tool and link them to broad categories.
4. Design a useful flowchart that an Engineer without any necessary previous knowledge would be able to use to implement Complex Project Management methods.

As time permits:

5. Examine Complex Project Management implementation in government and private business to see issues with its use and areas that can be addressed with the Research Project.

AGREED \_\_\_\_\_(student) \_\_\_\_\_(supervisor)

Date: / / 2015

Date: / / 2015

Examiner/Co-examiner: \_\_\_\_\_