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Complex Infrastructure Projects: A Systemic Model for Management

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Large infrastructure projects exhibit characteristics that might be able to be explained in terms of complex adaptive systems. Size, technical challenges, unclear or unshared goals and changes to context over time are the major sources of complexity. These sources of project complexity have important implications for management of large infrastructure projects. Drawing upon findings from the research literature in combination with the authors' personal industry experience and evidence from other practitioners, this paper uses ideas from complex systems thinking to inform the applied discipline of project management in order to explore the challenges offered by such projects. The paper advances the idea that such projects are more effectively managed systemically, as interrelated groups of projects or programs, with discreet management strategies chosen to address the specific sources of complexity. Synthesized in the form of a model, the aim is to stimulate discussion about strategies for managing complex infrastructure projects.

Introduction

The complexity inherent in large-scale infrastructure projects means that conventional project management approaches are often ineffective. The paper begins by introducing the idea that complex projects exhibit characteristics that can be readily understood through the terminology of complex adaptive systems. A brief discussion follows outlining how understanding the nature of project complexity can positively influence decisions about how the projects can be managed. Finally we present a model for thinking systemically about complex infrastructure projects.

Too many large infrastructure projects are failing (Williams, 1999, 2002; Flyvberg, 2003). Evidence is mounting that complex infrastructure projects exhibit qualitatively different characteristics to projects from traditional project-based disciplines, such as construction and engineering projects, on which much project management thinking has been formulated (Koskela & Howell, 2002; Costello et al, 2002). Processes for managing projects have been based on control theories (Yeo, 1993) and 'hard' systems thinking (Winter & Checkland, 2003). These methodologies assume that outcomes can be clearly defined, agreed and adhered to, that technological issues can be solved early in the life cycle of the project and that the project can be managed within a relatively stable context (Hobbs & Miller, 2002; Remington & Crawford, 2004). With large infrastructure projects conditions such as these are often the exceptions (Williams, 2002; Flyvberg, 2003).

Complex projects and complex adaptive systems

The literature on complex adaptive systems and systems thinking can help describe many of the characteristics of complex infrastructure projects which make their management problematic. Complex projects often exhibit a rapid change from one state to another. They can continue apparently according to plan for a very long period and then suddenly reach a point where change seems to be occurring in all parts of the project at once. This can be thought of as a phase change. Like complex adaptive systems complex projects exhibit different degrees of non-linearity (Beeson and Davis 2000). This can be caused by positive feedback loops occurring when the risks are triggered that mutually reinforce other risk outcomes. In complex projects we can also observe the propensity for self-organisation or adaptiveness that may be out of the direct control of those managing the project. During such projects, new and unexpected pairings and groupings of people might occur, unanticipated cultural territories and political coalitions can become apparent presenting challenges for management that are extremely difficult to predict. Sensitive dependence on initial conditions is also a feature shared by complex adaptive systems and complex projects. A small change in initial conditions can have a profound effect on system outputs (Mumby, 2005). Traditional risk management approaches, based on linear thinking, are not very effective as predictors of emergent characteristics, particularly as complexity increases during implementation.

We argue that people responsible for planning and implementing complex infrastructure projects should be able select from a multitude of methodologies or paradigms in order to manage the projects successfully. This can be referred to as 'systemic pluralism' – *systemic* in that we need to recognise that these projects have many characteristics in common with complex adaptive systems – *pluralism* in that we cannot restrict ourselves to one paradigm when thinking about appropriate management strategies (Munro & Mingers, 2002; Mingers & Brocklesby, 1997; Midgley, 1997). 'Hard' systems thinking, 'soft' systems thinking and thinking in terms of 'complex adaptive systems' are all appropriate depending upon the aspect of the project under consideration (Jackson & Keys, 1984; Flood & Romm, 1997; Flood & Jackson, 1991). For example, traditional project management methodologies provide very efficient ways of managing those parts of a complex project that can be clearly defined and for which firm contracts can be negotiated. However when characteristics of complexity are present the manager needs to be able to move freely between paradigms and build methodologies based on his/her interpretation of the situation (Midgley, 2000; Gregory, 1996).

Managing project complexity through a program

Project complexity is not a single, unvarying attribute. The nature of complexity can vary in different parts within the project. It is helpful therefore to think of any large project as a group of related smaller projects, commonly referred to as a program (Thiry, 2006). Turner and Cochrane (1993) classified projects into four types based on their degree of clarity or certainty about goals and methods. Following this, one of the first to explicitly recognise that projects exhibited different kinds of complexity was Williams (2002) who identified two kinds of complexity found in projects. He described projects with many interdependent elements as

having 'structural' complexity and projects having unclear goals and methods as being characterised by 'uncertainty'. Remington et al., (2006) have further developed Williams' categories, identifying four distinct categories of complexity encountered in projects. Any project might exhibit any one or all of these aspects of complexity. The larger the project the more likely it is to exhibit many aspects of complexity. We argue that it is helpful to be able to recognise the nature of the complexity being encountered when designing the management structure for these projects.

Infrastructure developments are typically too large to be managed as a single project or initiative. In order to manage systemically, which implies taking both an overview and detailed views of the individual initiatives, large projects are best conceptualised as integrated group of projects, or programs (Thiry, 2004). This enables the program to be designed so that each project within the program is small enough to be the responsibility of a single manager or management team. Within a program, the projects are typically interconnected. Their impacts on each other, in terms of risks and resource use, can be tracked at the program level and appropriate action can be taken to manage risks and distribute resources effectively. Most importantly, changes in the environment can be tracked, the impact on any project assessed and action taken to continue, change or eliminate that particular project from the program. This model for management requires a manager or management team responsible for managing the program. It also requires that the program management team be in direct contact with those responsible for organisational strategy. The model is summarised in Figure 1.

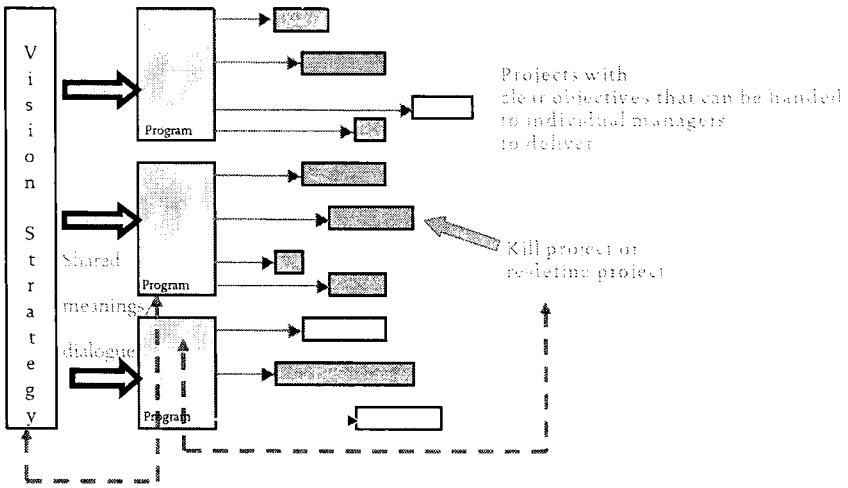

Figure 1 *Translation of the strategic vision through programs of projects that can be monitored and redefined as necessary in response to changes in strategic direction.*

Decisions about how best to implement the projects within the program relate specifically to the nature of project complexity expected. For instance there might be some projects within the program that exhibit very little complexity. On a spectrum from control to chaos they exist at the control end. They have relatively few parts, objectives can be clearly defined and agreed, there are few technologi-

cal surprises and they will be unlikely to be affected by political or environmental change during implementation. These projects are most efficiently managed using traditional project management methods based on 'hard systems' thinking. Other projects within the same program may exhibit varying aspects of complexity. Understanding the nature of the complexity that characterises each project has important implications for a number of key decisions to be made about the projects, such as the project governance structure, role capabilities and the selection of key personnel, approaches to risk management, finance and procurement.

Governing complex programs and projects may offer challenges that are quite different from those found in functional organisations. The organisational structure for the program and each project within defines how information is exchanged formally and authority is allocated. Recent research (Helm and Remington, 2005) strongly indicates that the capabilities needed for role of the executive sponsor in complex projects may not be sufficiently understood. Evidence is also mounting about the importance of the role of the executive sponsor and the governing board which are now considered to be fundamental to project success in any large complex project (Crawford et al, 2006).

Appropriate selection of key personnel is critical for complex projects. Lack of appropriate resources and divided loyalties of project personnel are well recognised sources of project failure (Dinsmore, 1993). Project teams are often expected to work much longer hours than required by functional roles. Many personnel suffer from stress-related symptoms as a result (Birch and Paul, 2003). Finding appropriate personnel who have the ability to work with complex issues while under pressure is not easy. We often assume that a project manager's role is generic. However a person who is able to cope with political uncertainty and ambiguity, may not also be able to be sufficiently hard-nosed to manage multiple contracts and ensure strict time deadlines, or motivate designers and technical experts to deliver within a timeframe. Being able to identify the source and nature of the complexity may assist the program director to fit the nature of the complexity with people's capabilities.

A model for thinking about complex infrastructure projects

In the model below (Figure 2) we offer an approach to managing complex infrastructure projects that demands a systemic perspective and accommodates a pluralistic approach to methodologies selected for implementation. It must be stressed that although certain initial decisions, made when developing the first iteration of the program structure, may look like a top-down approach to planning, the model will not work unless it is iterative (Thiry 2006). In response to information coming from the project teams, regular re-evaluation and revision during the entire life cycle of the initiative should cause the program to expand and contract organically during the life cycle of the initiative.

The model suggests that the senior management team first identifies the nature of project complexity expected and devise a program of separate projects that reflects the various aspects of that complexity. This will have implications for the structure and capabilities of the governing board and for selection of key people to direct the program and manage each project within the program. Once the projects within the program have been defined, approaches to managing risk, finance and

procurement can be determined for each project. Key to decision-making also is knowledge of the cultures and constraints inherent in the organisations involved together with a detailed understanding of the roles and capabilities of the key people associated with the project.

Conclusion

Many projects exhibit characteristics that can be explained in terms of complex adaptive systems. This is a result of their size, technical challenges, unclear or unshared goals and unpredictable changes to the political and social context over time. These aspects of project complexity have implications for management. The model presented in this paper is intended to stimulate thinking about management strategies for complex infrastructure projects. We argue for the development of management strategies that specifically target the nature of the complexity, which may vary substantially, in different parts of a large infrastructure project. We therefore argue that any large infrastructure project be organised within an integrated framework of a program to allow for management approaches informed systems thinking. By adopting a pluralistic perspective management strategies may targetted specifically for each project within the program permitting more effective monitoring and strategic responses to contextual changes.

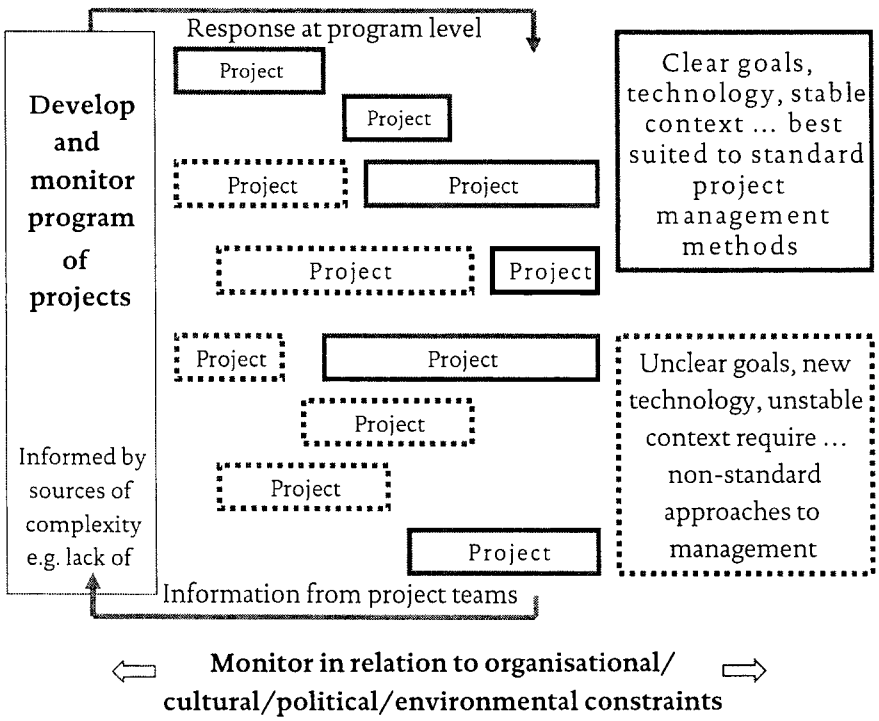

Figure 2 *A systemic model for thinking about complex infrastructure projects*

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Until very recently **Kaye Remington** was Course Director of the post-graduate Project Management program at the University of Technology Sydney. She teaches regularly overseas with recent appointments as a visiting academic at universities in France, Sweden and China. Prior to joining UTS in 1996 Kaye's 25-year career in project, program and senior management began in the UK where she worked on large-scale engineering and construction projects. Her career took her to Europe, the Middle East and back to Australia, where she founded her own consultancy practice. During that period she extended her expertise to projects in fields such as education, IT, HR and organisational change. Kaye consults regularly to a wide range of industries, including engineering, rail, housing, public works, water supply, power, banking, telecommunications and product manufacture. Recently she has also completed development and delivery of a large infrastructure program of 54 cross-organisational change projects encompassing specialist disciplines such as IT, HR, finance and facilities management, deemed a success by all key stakeholders. Together with Julien Pollack she is co-authoring a book, 'Tools for Complex Projects', due to be published by Gower Publishing in 2007, ISBN 0 566 08741 3. Kaye now balances a consultant practice with research and writing.

Julien Pollack has pursued a career that balances practice, research and teaching. He has taught project management at both post-graduate and under-graduate levels and has been an active member of the Project Management Research team at the University of Technology Sydney since 2000. In 2003 Julien won the Australian Institute of Project Management student medals for research into project management at both State and National levels and in 2005 he won the International PM Tage student research award, Vienna, Austria. From 2002-2005, while completing his PhD, he was Administrative Manager for the Health Professionals Registration Boards (HPRB) of NSW with responsibility for a large and complex infrastructure project involving formulation and implementation of a five-year plan for the strategic development of HPRB in relation to changing Government initiatives, management of information systems and information management projects and staff development and training in project management and information systems use. He

has authored and co-authored several refereed journal papers combining the fields of project management and systems thinking. Together with Kaye Remington he is co-authoring a book, 'Tools for Complex Projects', due to be published by Gower Publishing in 2007, ISBN 0 566 08741 3. Julien is currently working in Japan.

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Our efforts to sustain our communities, and the natural environments that support them, are challenged by our ability to communicate effectively between our different forms of knowledge. Respect for diversity and difference, drawing upon all our methods of inquiry, advocacy, and learning to find common ground, are all part of the integrative approach needed to address the complexity of the challenges we face.

This conference was an opportunity for practitioners from broad ranging traditions to share their experiences regarding integrative and innovative approaches that can make a difference.

Systems thinkers from across the globe were invited to participate in the conference through submitting a paper, contributing to workshops, and involvement in the range of planned and emergent activities. Papers were invited, on any aspects of relevance to the conference themes. The conference themes included:

- Resilience, ecology and governance;
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- Creativity, organisation and complexity;
- Systems thinking and dynamics;
- Social sustainability and community;
- Livelihood, innovation and opportunity;
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Dear Kaye Remington,

Thank you for submitting your abstract for the ANZSYS 2006 conference – "Sustaining Social and Natural Capital". Your abstract has been accepted and allocated to one of the plenary presentation themes.

The full papers for this conference are due on the 31st of July 2006. All correspondence and submission of papers should be directed to me at r.attwater@bmwhi.org.au. Papers will have a 2500 word limit and formatting should follow the guidelines at: http://emergence.org/ECO_site/web-content/sub_info.html

All full papers will be peer reviewed, and referee's comments will be returned to each corresponding author by 1st September. Authors are asked to make any necessary amendments in response to referee's comments prior to final submission of their paper by the 15th October 2006. All peer reviewed papers will be published on a CD of the conference proceedings with an ISBN, and provided as part of the registration pack.

I would also like to invite you to be involved in the peer review process of the conference papers. As well as fulfilling requirements for peer review, I intend this process to be supportive and undertaken in a spirit of mentoring. For each plenary theme, the anonymous abstracts will be circulated to participants in that theme. You are invited to express your interest in abstracts which you would like to referee. Each participant will be asked to referee two papers each, and clear instructions for referees will be circulated. All comments will be returned to me and I will then forward referee's comments to each corresponding author.

I hope that you will find this suggested process suitable, and look forward to your contribution.

Yours sincerely,

Roger Attwater
Conference Convenor