Managing project interdependencies: exploring new approaches

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1. Introduction

The interdependencies between projects create complexities for the management of project portfolios within organisations. In times of uncertainty this challenge is even greater due to the difficulties in predicting the flow-on effects from changes to projects in the portfolio. Hence, in times of disruptive change a good understanding of project interdependencies is particularly important.

This paper outlines two related studies that aim to improve the understanding and management of interdependencies within project portfolios. The paper first defines project portfolio management (PPM) and highlights its growing importance for optimising organisational outcomes, especially in dynamic environments. Project portfolio complexity and interdependencies between projects in a portfolio are then overviewed, highlighting the challenges that these interdependencies create for effective PPM, and introducing some of the methods used for understanding and managing these interdependencies including the dependency matrix and the related design structure matrix. Network analysis and mapping tools are then introduced and suggested as a novel method for improving understanding and managing project interdependencies. Finally, an example of the use of this type of method is presented and the current research projects are overviewed.

2. Project portfolio management (PPM)

The management of the project portfolio is central to organisational strategy and competitiveness as organisations aim to gain maximum value from project investments, and as most organisational innovation is done through projects. PPM capabilities aim to provide a holistic and responsive framework for the management of the project portfolio.

Projects are temporary endeavour undertaken to meet specific goals such as the development of new products or services or the implementation of organisational change [1, 2]. Organisations invest large amounts in these projects, however many projects are not successful. Research on project outcomes report success rates between 30 and 60 percent [3, 4, 5, 6]. Therefore there is significant scope for improved project success rates, and organisations actively seek new methods that may boost the return on their project investments. In order to maximise the return on project investments, organisations place high importance on PPM and embark on significant learning processes to enhance their capabilities [7].

PPM processes help organisations manage their portfolios of innovation projects through a range of tools and methods designed to generate and evaluate project information and to steer decision-making to maintain a balanced project portfolio that is aligned with strategic goals [8, 4]. There has been a surge of interest in PPM in recent years as innovation has become understood as the main driver of economic growth in developed nations and as organisations have become increasingly project-based [9, 10, 11].

PPM is a rapidly developing field for innovation research and practice, and awareness and application of PPM practices is growing. Levine [8:22] offers the following concise and generic definition of PPM: “Project portfolio management is the management of the project portfolio so as to maximise the contribution of projects to the overall welfare and success of the enterprise”. While project management methods focus on ‘doing projects right’, PPM is a ‘dynamic decision process’ that focuses on ‘doing the right projects’ to ensure that organisational resources are allocated to the best combination of projects to meet financial, strategic and other organisational goals [4].

The literature indicates that managing a portfolio of innovation projects presents a multi-dimensional challenge that is often addressed through a PPM capability with a formal and structured process [4, 12, 13]. A growing body of literature on PPM outlines processes, methods and tools and identifies the 'best practices' associated with better outcomes [14, 15, 16, 17]. The PPM literature suggests that a variety of methods and approaches can be applied to the problem. Some PPM processes attempt to apply numerical models similar to those used for financial portfolio management. However, these models have not been successful due to the complexity of the project environment, and the necessity to incorporate multiple types of information to assist optimisation decisions along several dimensions [18]. The many types of information include financial factors as well as many others such as those related to resources, strategy, risk, interdependence, timing, and customers. Research indicates that 'best practice' organisations make PPM decisions in meetings, and that graphical methods such as portfolio maps and other graphical and visual information displays facilitate the ongoing group decision-making for resource allocation, reallocation and reconfiguration [17, 19, 20]. A PPM capability can enable an organisation to effectively respond to dynamism in the environment through this ongoing resource reconfiguration.

3. Project interdependencies

Interdependencies within project portfolios are based on multiple interrelated factors such as resource and time constraints, financial costs, project outcomes and risk profiles. In times of uncertainty and change, organisations face heightened challenges in managing their project portfolios – prompting initiatives to improve upon current management techniques such as the research outlined in this paper to improve the understanding of project interdependencies.

Project interdependencies are acknowledged as an important factor in PPM decision making [21, 22]. Projects are said to be interdependent when the success of a project depends upon other project(s). Eilat, Golany and Shtub [23] identify three types of interdependencies: resource interactions (the need to share resources or wait for scarce resources until they are released by another project), benefit interactions (complementary or competitive effects) and technical dependence. Other types of dependencies that may exist between projects in a portfolio include outcome dependencies (the need to use the end result of another project – these can be technical or other outcomes) and learning dependencies (the need to incorporate the capabilities and knowledge gained through another project). Learning-based project interdependencies are especially challenging to manage due to the difficulties in codifying project knowledge and transferring that knowledge between projects in the portfolio.

Organisations manage dependencies between projects using a variety of methods. Management strategies to improve between-project communication are recommended in the literature [24, 25]. Resource dependencies are often addressed by scheduling optimisation systems [12]; however these types of systems require large amounts of numerical input and are not considered useful in most PPM environments. Dependency matrices are a more common method that are used to provide a view of interdependence between projects [26, 27]. The dependency matrix is similar to the design structure matrix (DSM) that is applied in development environments to manage interdependent tasks [28, 29, 30]. In a DSM, the rows capture the information inflows, whilst the columns capture the information outflows between components or sub-projects in a given system [31], whereas in a dependency matrix, inward and outward between-project dependencies are captured. The goal of DSM is to analyse the elements within a system and re-sequence these in order to minimise iterations and their scope [28]. There are two types of DSMs, the static DSM that uses clustering algorithms and the time-based DSMs that use partitioning algorithms [31]. DSM analysis can be used to optimise and restructure operations; however this analysis does not reveal accumulated or multi-level interdependencies.

Methods for managing project interdependencies currently lack the ability to highlight the most important projects based on cumulative dependencies in the portfolio. Dependency Matrices use a two dimensional grid to display and analyse bi-directional dependencies between each pair of projects in a portfolio. The rows and columns are each labelled with the set of projects in the portfolio as illustrated in Figure 1. There are a number of types of dependencies that may exist between projects such as resource dependencies, time-based dependencies and outcome based dependencies in addition to information or learning-based dependencies; the dependency matrix can be used to capture a range of dependencies.

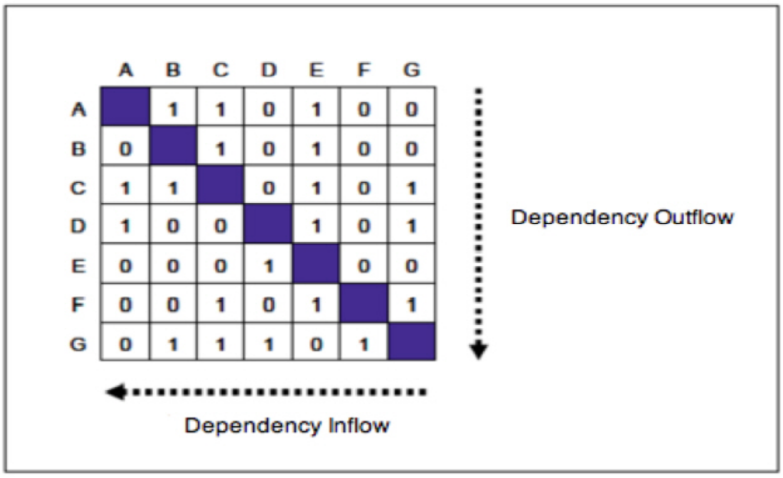

Figure 1: Dependency Matrix illustrating inward and outward dependencies between projects A-G (based on [31:2])

However, the dependency matrix in Figure 1 does not clearly reveal the relationship between projects F and A in Figure 1. The matrix shows that project F is dependent upon project C, and on a different line shows that project C is dependent upon project A. The resulting dependency between project F and project A is not clearly indicated on the dependency matrix in Figure 1. Understanding these multi level relationships is important to fully understand project interdependence in a portfolio. Therefore, to improve the management of project portfolio investments and enhance outcomes, there is a need for a better method to aid the understanding of multi-level project interdependencies. Network mapping and analysis tools have the potential to enhance this understanding. Dependency matrix and DSM concepts and methods are related to network precedence diagrams and network analysis diagrams [28]. The application of network mapping tools or the combination of tools may provide a powerful method for analysing the interdependency relationships within project portfolios.

4. Network mapping and analysis

Network analysis and mapping tools build on mathematical modelling and graphical methods to help understand and analyse networks. Network analysis has its origins in graph theory [32, 33], which is a mathematical discipline that examines the relationships between a set of entities referred to as vertices or nodes [34]. Nodes are connected by edges, more commonly known as links or ties. A graph consists of a set of nodes and the ties between these pairs of nodes. Outside of strictly mathematical applications the term network is a little more relaxed. Brandes & Erlebach [32:7], for example, say the term network refers to "the informal concept describing an object composed of elements and interactions or connections between these elements". Caldarelli & Vespignan [35:5] link the notions of a system and graph to describe a network as: "a graph whose nodes (vertices) identify the elements of the system. The set of connecting links (edges) represents the presence of a relationship or interaction among these elements".

Network mapping tools have the ability to map relationships between nodes in a network at multiple levels and may reveal accumulated effects that are not evident in single-level relationship analysis [36]. The mapping is done through the use of software-based tools that help to record, analyse and visually display the relationships between items or 'nodes' in a network. Computerised tools are used for network analysis due to their ability to handle large amounts of data and to analyse and display the data in a graphical form. Enhanced analysis of the data is provided by using such maps to illustrate proposed or actual changes in the network. The graphical displays provide an intuitive and easy-to-interpret format that can help reveal patterns that are not revealed by verbal explanations or matrix displays of data [37].

Social network analysis (SNA) and the related organisational network analysis methods are a common application of network mapping where relationships between people or organisations are analysed and presented in a visual form [38]. The network mapping exercise involves collecting data from people representing each 'node' of the network on their interaction and relationships with other 'nodes'. For SNA the 'nodes' are individual people who answer questions about their interactions with other people. SNA is shown to be an aid to understanding and improving relationships between networks of people or organisations [39, 36, 40]. For example, SNA has been shown to be effective in promoting collaboration, supporting critical nodes in the network, and in managing and maintaining networks during organisational restructuring [40].

There are many other existing applications for network mapping. These include mathematical, biological and economic modelling [37]. Network mapping has also been used in conjunction with design structure matrix (DSM) tools to manage interdependencies between tasks in product development environments [41, 31]. In these environments network mapping and analysis is shown to help determine the key relationships in a complex development environment and to show the impact of making changes to tasks [42]. Product development team interactions and information flows were measured in another study that demonstrated the use of network mapping and analysis in identifying the most important nodes in the network [41]. These studies show the benefits of network mapping for networks of teams or tasks involved in complex product development.

These findings indicate that network mapping and analysis may have benefits for the understanding of project interdependencies. There are currently no published studies on the use of network mapping and analysis to study networks of projects in a project portfolio. However, initial tests have been performed as part of a larger PhD study on *Visualising Collective Knowledge to Manage Complexity in a Portfolio of Projects* [43]. These tests have indicated that network mapping and analsysis can be useful for project, program and portfolio management by considering each project as a 'node' in the network and capturing and displaying information on the relationships or interdependencies between nodes. One benefit of network mapping and analysis illustrated by Durant-Law's work is shown in Figure 2. This figure presents two network mapping visualisations of the same portfolio of projects. The projects in the view on the left are indicated by circles sized to indicate the level of investment in the project. The level of investment is often assumed to be a proxy measure of the relative importance of the project within the portfolio. The view on the right displays the project size to indicate the number of projects that are dependent upon a project. This view provides a very different picture of project importance based on the analysis of interdependencies within the portfolio. Identical projects are circled in each view to highlight the difference in the types of information in each choice of display.

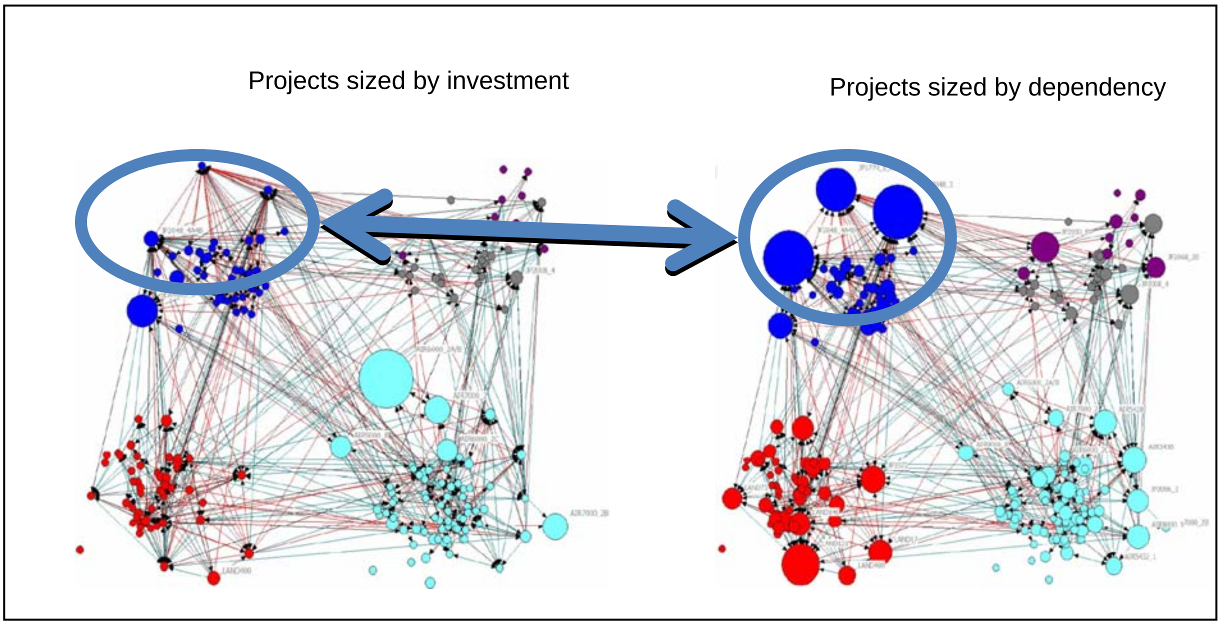

Figure 2: Network maps of a project portfolio illustrating interdependencies [43]

Network maps are also useful for helping organisations visualise multi-level dependencies. For example a network map reveals whether a project is indirectly dependent upon another project. For example, Project A's dependency list may include Project B but not Project C. If Project B's dependency list includes Project C, this indicates that Project A also depends upon Project C, however matrix based methods of analysing project dependencies are difficult to analyse and 'see' these dependencies. Figure 3 presents a portion of a network map showing this type of relationship and illustrating the improved visualisation of multi-level dependencies afforded by network mapping and analysis of projects in a portfolio. This map illustrates all of the projects that Project X depends upon, making the relationships clearer and helping to ensure that multi-level dependencies are acknowledged. As shown in Figure 2, although Project X's dependencies may only include two other projects (A and Y), the multi-level dependency chain shows that Project X's success depends upon four additional projects (B, C, D and Z). Using this approach it is possible to see and analyse second-order and beyond relationships.

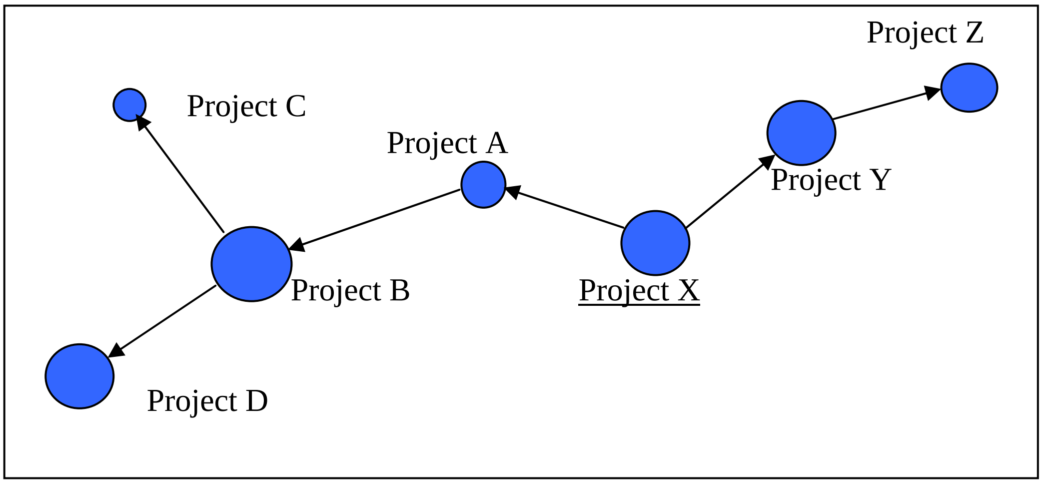

Figure 3: Portion of a network map illustrating multi-level dependencies for project X

5. Research method

The two studies outlined in this paper address the identified need for improved methods for understanding interdependencies between projects in a portfolio. In the main study, network analysis and mapping tools are being used to create visual network representations of the project portfolios at three case organisations. A second study will extend the analysis at one of the organisations by comparing network analysis and mapping with other methods for understanding project portfolio interdependencies. These studies are currently being completed and final results will be available early 2010.

The main study employs a three-phase method to evaluate the project environment and a selected project portfolio at three case organisations. This study aims to measure the relationship between the use of network mapping tools and an organisation's understanding of its project portfolio interdependencies. The organisations selected for the study have complex portfolios with multiple interdependencies. This multiple-case study method develops a rich picture of the nature of the dependencies between projects in the portfolio, the effects on these interdependencies on the project environment and portfolio outcomes, and the relationship between the level of understanding of the project interdependencies and the portfolio performance at each organisation. Cross case comparisons and analysis will be conducted to evaluate and test the findings across project environments. Each case study will focus on a selected portfolio with between about 30 and 70 projects – these limits have been selected to ensure that enough data is available for analysis – but to keep the scope of the research within manageable bounds.

During the first phase of the research at each organisation, the organisational environment and the nature of the interdependencies between the projects in the portfolio will be investigated through semi-structured interviews and analysis of other organisational documents when possible. The bounds of the portfolio for the study will be identified during this phase. The second phase, the data collection phase, first incorporates the findings from the first phase to customise the data collection instrument to include the projects in the relevant portfolio and to capture the nature of dependencies based on the types of dependencies experienced by that organisation. Project managers responsible for the identified projects each complete a survey using the ONAsurveys survey tool[1]. The ONAsurveys tool is designed for the analysis of organisational networks and

[1] ONAsurveys is a tool for capturing network data for display in network maps - www.ONAsurveys.com.

has been customised for this research including the addition of a range of additional questions to better understand the project environment. During this second phase, a group of senior portfolio stakeholders will complete a separate survey to assess their current impressions of the relative importance and critical dependencies between projects in the portfolio and to capture their impressions on the performance of the overall project portfolio. At the completion of the second phase, the data is analysed using network mapping and analysis tools [44], and these findings compared with the senior project stakeholders' impressions. The final phase of the study involves presenting the findings to the case organisations' senior project stakeholders and collecting feedback and impressions through a semi-structured feedback session.

The second study extends the analysis conducted in the main study at one of the case organisations. The second study will compare and contrast several methods of understanding project portfolio dependencies by using multiple tools such as dependency matrices or design structure matrices to analyse the same portfolio. Each tool's ease of use, information gained, and applicability to a range of project portfolio management problems such as scheduling, prioritisation and change management will be explored. This second study will also investigate whether a combination of methods will best enhance understanding of a project portfolio.

6. Conclusion

In order to best manage their project portfolios, organisations need to understand the interdependencies between projects. Project and portfolio complexity and dynamic environments create challenges for the understanding of these interdependencies, and there is a need for better methods and tools to aid in this understanding. The research introduced in this paper investigates network mapping and other graphical methods for capturing, displaying and updating information on dependencies between projects in a portfolio. Graphical methods and visual information displays have been shown to facilitate group PPM decision-making indicating that the graphical and visual methods investigated in this study may also strengthen PPM processes.

Network analysis and mapping tools use visual network mapping displays while the dependency matrix presents data on a grid to highlight project interdependencies. Network mapping and analysis is a novel approach for the study of relationships between projects in a portfolio. These network analysis tools have become popular for the study of relationships in social networks and initial results indicate benefits for the study of project relationships.

Building upon initial findings that illustrate the benefits of network mapping as a visualisation tool in a project portfolio environment, the research projects outlined in this paper will test the applicability of network analysis and mapping tools in a range of environments. The research will investigate relationships between the use of network mapping, understanding of project interdependencies, and project portfolio management outcomes, and will also compare and combine network analysis and mapping tools with dependency matrix and DSM tools for the capture, analysis and communication of project interdependencies.

Network mapping and analysis tools and dependency matrix tools have been chosen for the study because of their potential to enhance the understanding of project interdependencies to ensure that decisions are better informed. These informed decisions are expected to improve the outcomes from investments in an organisation's project portfolio. The project will contribute to the engineering and project management community by investigating new methods of understanding project interdependencies and using the findings to improve organisational PPM capabilities – thus enabling those organisations to more dynamically respond to environmental change.

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