Management Science methods and methodologies for Project Management: What they model, how they model and why they model

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Nowadays there is an enormous variety of methods, techniques and methodologies within the broad field of Management Science, all having very diverse characteristics and stemming from various paradigms based on different philosophical assumptions, and, to a lesser or greater extent, drawing on particular bodies of theory. Whilst this plenitude can enhance practice, it also poses problems for project managers who often tend to restrict themselves to one paradigm or even one methodology. The aim of this paper is to assist project managers in understanding both the implicit and explicit assumptions underlying management methods and their principal aims and purposes. Thus, project managers will be able to make a choice as to which methodology is more appropriate for a particular situation.

INTRODUCTION

Project management is anything but universal (Senhar 1998). For sixty years, organizations have increasingly been using projects and programs to achieve their strategic objectives (Bredillet et al 2015). Projects have traditionally been the prerogative of the engineering disciplines, but with the dynamics of business, project management has moved into business' main street. Today project managers have gained recognition and employment opportunities beyond construction, aerospace and defense, in pharmaceuticals, information systems, and manufacturing. In this context, project managers must not be limited to a monitoring and reporting role at an implementation level. They must be involved at strategic levels with the possibility and authority to effectively influence the direction and course of a project. A good Project Manager must have the skills needed to make sound decisions, consistent with the global strategy of the project, taking into account, not only the relationships of the different actors involved in the project, but also the possible impact of his/her decisions on project performance.

The aim of this paper is to assist project managers in understanding both the implicit and explicit assumptions underlying management methods and their principal aims and purposes, in order to be able to make more informed and critical aware decisions. The paper begins by differentiating the terms methodology, method and technique. Next, the main management science methods classified according to three questions: what they model, how they model, and why they model, are presented. Finally, there is a concluding section with the main findings of the paper.

METHODOLOGY, METHOD AND TECHNIQUE

The terms methodology, method and technique can have several overlapping meanings. A methodology can be the general study of methods of research or intervention, or the particular methods used in a specific project, or a generic combination of methods that is commonly used as a whole. In other words, a methodology is a structured set of methods or techniques to assist project managers in undertaking research or action. Generally, a methodology will develop, either explicitly or implicitly, within a particular paradigm and will embody the philosophical assumptions and principles of the paradigm.

A method is a specific activity that has a clear and well-defined purpose within the context of a methodology. Examples of methods are developing a simulation model, a PERT network or the earned value management method. Methods may be complementary within a methodology if, for example, we combine together statistical analysis, building a simulation, and sensitivity analysis; or methods may also be substitutes. The relation between methodology and method can be seen as the relation between a what and a how (generally, each what has a number of possible hows). Whereas the methodology specifies what type of activities should be undertaken, the methods are particular ways of performing these activities. Finally, a technique is a tool that can be used to perform a particular method, for example a linear programming optimizer.

Although project managers, implicitly or explicitly, use these three concepts, it is only by reflecting on their relationships that helps to assess the scope of the management science method used. As Mingers (2003) states, one way of seeing the interconnection between these three concepts is to realize that the paradigm gives the philosophical support to the general question of why we act and intervene/no intervene in a particular way; a methodology sets out the guidelines on what activities need to be carried out in the intervention, and methods/techniques will describe how the activities are going to be carried out (Mingers 1997, Paucar-Cáceres 2010).

MANAGEMENT SCIENCE

Project Management is discussed both in management science and in operations research. Application of operations research and management science started more than half a century ago, although historically, operations research came first. The scope and ways in which management science, the application of scientific method to management, are conceived and used have changed enormously. Its methods and methodologies have been applied to a large variety of management situations. Management science is not only viewed as the application of classical operations research techniques. It is a recognized discipline that tackles a wider scope of managerial problems with a number of sophisticated approaches and has influenced the field of management and, at the same time, has been influenced by adjacent fields borrowing and adopting frameworks and models from other areas of management (Paucar-Cáceres 2010).

Management Science tends to focus on quantitative tools and the soft skills necessary to manage projects successfully. Management Science is far from being a robust body of scientific knowledge in the way say that physics or chemistry is, in the sense that there can be reducible, repeatable, and refutable laws of management (Morris 2004).

Management science is essentially about taking action. It provides project managers with particular interventions that they can undertake in response to questions that they have about they might transform some aspects of a situation. Nowadays, there is an enormous variety of methods, techniques, and methodologies within the broad field of management science, all having very diverse characteristics and stemming from various paradigms based on differing philosophical assumptions, and, to a lesser or greater extent, drawing on particular bodies of theory. Whilst this plenitude can enhance practice (Mingers and Brocklesty 1997), it also poses problems for project managers who often tend to restrict themselves to one paradigm or even one methodology. It is necessary to make a choice as to which method/methodology is appropriate for a particular situation.

All management science methods have in common some form of modelling, but they differ in terms of what they model (ontology), how they model (epistemology) and why they model (axiology). For example, network models represent the activities of a project and the precedence relationships among them (what they model). By modelling activities' attributes and resources (how they model), project managers use these models to analyze the schedule information and to explain the sequencing need for project activities (why they model). Table 1 shows the main management science methods classified according to these three questions.

Table 1. Main management science methods utilized in project management

	A system to	By modelling	In order to
Network models	Represent the component activities of a project and the precedence relationships among them.	Activities' attributes, resources, constraints…	To analyze the schedule information and explain the sequencing need for project activities.
Multi-objective decision-making	Model the relation between the measurable attributes of entities and processes and to optimize the value of an objective(s) function using linear and nonlinear equations	Linear and nonlinear variables, constraints.	Evaluate many different options and decisions thereby optimizing an objective
Multi-criteria decision-making	Make decision in the presence of multiple and often conflicting criteria	Activities' attributes (time, cost, safety, quality, etc.)	To evaluate, rank and select the best option from a group of alternatives
Game theory	Model the evolution of a conflict or competitive situations involving different players and interacting decisions and strategies using a variety of game-theory-based modelling tools	Activities' attributes (time, cost, etc.)	To explain the behavior of two or more players, i.e., owners, constructors, and explore different solutions among them.
Dynamic programming	Model situations where decisions are made at stages and to determine a strategy which is optimal in a multi-stage decision problem.	Activities' resources	To explore the operation of complex real-world project situations to aid understanding and control.
Forecasting models	To forecast the future value of measurable attributes of entities and processes as a function of past data.	Activities' attributes (time, cost, etc.)	To predict the behavior of real-world systems and obtain reliable warnings so that this behavior can be changed or anticipated.
Simulation models	Simulate the behavior of a project with stable patterns of statistical behavior and the activities their undergo	Activities' attributes (time, cost, etc.)	To explore the operation of complex real-world interactions between discrete entities to increase understanding of their behaviour in the project.
Markov model	To model stochastic or random processes in which transitions between states as well as the time the system spends in each state are random.	Probabilities, time	To address stochastic scheduling problems and risk evaluation.
Data Envelopment Analyses (DEA)	To calculates the relative efficiency of multiple projects on the basis of observed inputs and outputs	Inputs: resources; Outputs: time, cost	To evaluate and select projects in a multi-project environment

Source: adapted from Mingers 2003

Network models

The US Navy's successful application of PERT to the development of the Polaris Fleet Ballistic Missile System in 1958 generated a very large body of network analysis methodology (Moeller and Digman 1981). Since then, networks of flow have been extensively studied in the literature (Ford and Fukerson 1962, Charnes and Cooper 1962, Elmaghraby 1964). Networks models represent the component activities of a project and the precedence relationships among them. By modelling variables such as activities, resources, constraints, etc., network models are used to analyze the schedule information of a project and to explain the sequencing need for the project activities. The theory of networks has played an important role in the planning and scheduling of projects primarily because of the ease with which these projects can be modelled in network form.

Multi-Objective Decision-Making

Traditional research on project schedule and management focuses on one objective, either the shortest possible project duration or the minimum possible cost. However, in most situations, the optimization problems are multi-objective, where two or more independent objectives, such as the utilization of resources available and the balance of workload, must be optimized simultaneously. In these cases, multi-objective decision making methods are helpful tools for project managers. These techniques model the relation between the measurable attributes and processes of a project and, using linear and nonlinear equations and constraints, these models evaluate many different options and decisions thereby optimizing several project objectives.

Multi-Criteria Decision-Making

Projects managers are usually faced with decision environments where there are a number of conflicting criteria such as cost, time, safety, etc. Multi-criteria decision-making or multi-criteria decision-aid methods belong to a class of operations research models which deal with the process of making decisions in the presence of multiple criteria. By modelling attributes such as time, cost, quality, and safety, multi-criteria methods evaluate, rank and select the best option from a group of alternatives. These methods, which can handle both quantitative and qualitative criteria, share the common characteristics of conflict among criteria, incommensurable units and difficulties in design/selection of alternatives (Pohekar and Ramachandran 2004).

Game theory

Game theory can be defined as the study of mathematical models of conflict and cooperation between intelligent and rational decision-makers (Myerson 1991). In game theory individuals or groups become players when their respective decisions, coupled with the decisions made by other players, produce an outcome. The options available to players to bring about particular outcomes are called strategies. Strategies are linked to outcomes by a mathematical function that specifies the consequences of the various combinations of strategy choices by all of the players in a game. A coalition refers to the formation of sub-sets of players' options under coordinated strategies. In project management, game theory can be used to model the evolution of a conflict involving different players, such as owners, contractors, or project managers, and explore different solutions among them.

Dynamic Programming

Of all mathematic techniques employed in operations research, dynamic programming is perhaps the simplest in concept and one of the most difficult to apply due to the lack of a clear-cut formulation and solution algorithm (Shamblin and Steven 1974). By modeling project resources, dynamic programming is used to model project situations where decisions are made at stages, in order to determine a strategy which is optimal to explore the operation of complex real-world project situations.

Forecasting models

Forecasting is a critical component of project management. The effectiveness of a project control relies on the capability of project managers to make reliable forecasts in a simply manner. Project managers must be able to make reliable predictions about the final outcomes of projects and such predictions need to be constantly revised and compared with the project outcomes. In order to predict project outcomes and obtain reliable warning so that this outcomes can be changed or anticipated, forecast models predict, by modelling past data, the future value of measurable attributes of the project.

Simulation

Simulation is a very powerful and widely used management technique for the analysis and study of complex systems. Simulation may be defined as a technique that imitates the operation of a real-world system, i.e, projects, as they evolve over time. This is normally done by developing a simulation model, which takes the form of a set of assumptions about the operation of the system, expressed as mathematical or logical relations between the objects of interest in the project. In contrast to the exact mathematical solution available with most analytical models, the simulation process involves running the model through time to generate representative samples of the measures of performance.

Markov models

Traditionally, the progress of a project is measured by the stage which has been reached. However, when loops occur, progress is not represented by the furthest stage which the project has reached, for there is a significant probability that the project will revert to an earlier stage at some subsequent time. Existing project duration prediction models do not recognize the impact of earlier problems on later delays. Markov modelling is a classical technique used for assessing the time-dependent of many dynamic systems. A Markov model is a mathematical system characterized with the property of memoryless, that is, the next state depends only on the current state and not on the sequence of events that precede it. Markov models are used for describing systems in which transitions between states as well as the time the system spends in each state are random. What happens next depends only on the current state of the system. Thus, Markov models are frequently used to address stochastic scheduling problems and risk evaluation.

Data Envelopment Analysis

In today's competitive business environment, companies need to continuously invest in both consecutive and simultaneous projects to guarantee healthy and profitable growth. Companies are being forced to improve their effectiveness and efficiency looking for effectively comparing the performance of various projects at a given time period (Vitner et al 2005). DEA is a mathematical programming technique that provides the correct method for project evaluation and selection (Charnes et al 1978). DEA calculates the relative efficiency of multiple projects on the basis of observed inputs and outputs. The DEA approach is used for evaluating the performance of projects in a multi-project environment where each project is considered a decision-making unit having its own inputs and outputs where the inputs represent the resources to perform the project, and the inputs represent all of dimension by which the project is measured.

CONCLUSION

Project managers are usually faced with decision environments in which there are a number of conflicting objectives, criteria, and limited resources, or they have to deal with conflict situations involving owners and contractors and need to explore different solutions among them, or project managers must be able to make reliable predictions about the final outcome of projects, or even evaluate and select the performance of projects in a multi-project environment. Whilst there is an enormous variety of methods within the broad field of management science, project managers must be able to understand the aims and purposes of each method in order to choose one method over another for a particular situation. This paper reviews the main management science methods according to three questions: what they model, how they model, and why they model. By answering these three questions, project managers will be able to make a choice as to which method is more appropriate for a particular intervention.

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