GOWER
Applied Research

Management Science, Operations Research and Project Management

Modelling, Evaluation, Scheduling, Monitoring

José Ramón San Cristóbal Mateo

Management Science, Operations Research and Project Management

JOSÉ RAMÓN SAN CRISTÓBAL MATEO
University of Cantabria, Spain

GOWER

© José Ramón San Cristóbal Mateo 2015

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without the prior permission of the publisher.

José Ramón San Cristóbal Mateo has asserted his right under the Copyright, Designs and Patents Act, 1988, to be identified as the author of this work.

Gower Applied Business Research
Our programme provides leaders, practitioners, scholars and researchers with thought provoking, cutting edge books that combine conceptual insights, interdisciplinary rigour and practical relevance in key areas of business and management.

Published by
Gower Publishing Limited
Wey Court East
Union Road
Farnham
Surrey, GU9 7PT
England

Gower Publishing Company
110 Cherry Street
Suite 3-1
Burlington, VT 05401-3818
USA

www.gowerpublishing.com

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN: 9781472426437 (hbk)
ISBN: 9781472426444 (ebk – ePDF)
ISBN: 9781472426451 (ebk – ePUB)

Library of Congress Cataloging-in-Publication Data
San Cristóbal Mateo, José Ramón
Management science, operations research and project management : modelling, evaluation, scheduling, monitoring / by José Ramón San Cristóbal Mateo.
pages cm
Includes bibliographical references and index.
ISBN 978-1-4724-2643-7 (hardback) -- ISBN 978-1-4724-2644-4 (ebook) -- ISBN (invalid) 978-1-4724-2645-1 (epub) 1. Project management. 2. Management. 3. Operations research. I. Title.
HD69.P75S3242 2015
658.4'04--dc23

2014029453

MIX
Paper from responsible sources
FSC® C013985

Printed in the United Kingdom by Henry Ling Limited,
at the Dorset Press, Dorchester, DT1 1HD

Management Science, Operations Research and Project Management

Contents

List of Figures *vii*
List of Tables *ix*

Introduction 1

1 **Network Models** **13**
Types of Network Representations 13
Characteristics of Network Models 16
Types of Networks 19
Decision-CPM Model 20
Generalized Network Model 29
Decision Box Network 30
Graphical Evaluation and Review Technique (GERT) 33
Venture Evaluation and Review Technique (VERT) 42
Generalized Alternative Activity Network Model (GAAN) 44

2 **Multi-Objective Decision-Making Models** **49**
Linear Programming Formulation of the Time-Cost Trade-off Problem 49
A Linear Time-Cost Trade-off Model to Find the Critical Path 54
Fuzzy Linear Programming 56
Goal Programming 63
An Integer Programming Problem 67

3 **Multi-Criteria Decision-Making Models** **73**
Multi-Attribute Utility Theory 73
The VIKOR Method 83
The TOPSIS Method 85
Fuzzy PROMETHEE Method 90

4 **Game Theory** **101**
Game Theory 102
The Shapley Value 105

此为试读,需要完整PDF请访问: www.ertongbook.com

	Allocation of Benefits Resulting from Cooperative Behaviour Using the Shapley Value	106
	The Core	108
	A Cost-Allocation Method Based on the Core	110
	Float Allocation Using Game Theory	114
5	**Dynamic Programming**	**121**
	Dynamic Programming	121
	A Multi-Project Investment Problem	123
	Dynamic Programming Formulation of the Time-Cost Trade-off Problem	126
6	**Forecasting Models**	**133**
	Forecasting	133
	Linear Regression	134
	Grey Methodology	140
	The GM (1,1) Model	141
	Earned Value Management	150
7	**Simulation Models**	**157**
	A Simulation Model with Random Numbers	158
	Artificial Intelligence	162
	Expert Systems	162
	Artificial Neural Networks	169
8	**Markov Models**	**173**
	Markov Chain	175
	Risk Analysis Based on Markov Chains	183
9	**Data Envelopment Analysis Models**	**187**
	Data Envelopment Analysis	190
References		*199*
Index		*217*

List of Figures

1.1	Notation *AoA*	14
1.2	Notation *AoN*	15
1.3	Decision-CPM network	24
1.4	Decision set $\{S_{21}, S_{42}\}$	25
1.5	Decision set $\{S_{21}, S_{41}\}$	26
1.6	Decision set $\{S_{22}, S_{41}\}$	27
1.7	A generalized network model	29
1.8	Starting and finishing times in a generalized network model	30
1.9	Finishing time in a generalized network model	30
1.10	A decision box network	32
1.11	Types of nodes in a GERT network	36
1.12	Branches in series	36
1.13	Branches in parallel	37
1.14	Self-loop	38
1.15	A GERT network	40
1.16	A GAAN network	46
2.1	Network associated to the time-cost trade-off problem	51
2.2	Network associated to the fuzzy linear programming problem	59
2.3	Network associated to the goal programming problem	65
3.1	Utility curves	75
3.2	Network associated to a multi-attribute utility problem	76
3.3	Routes to assign utility values	79
3.4	Network associated to the VIKOR and TOPSIS application	87
3.5	Network associated to the fuzzy PROMETHEE application	95
4.1	Network associated to the Shapley value application	107
4.2	Network associated to the cost allocation problem	111
4.3	Network associated to a float allocation problem.	117
5.1	Network associated to the project	129
6.1	Scatter plot of *LnT* and *LnC*	136
6.2	α values	143
6.3	Actual cost and predicted value	150
7.1	Network associated to a simulation model	158
7.2	Distribution of the duration of the activities	161
7.3	S-curve	167

7.4	A feed-forward neural network	170
8.1	Linear network associated to the project	178
8.2	Prediction curve of cumulative probabilities for a 4-stage project	181
8.3	Probability of completion of a 4-stage project with varying reversion probabilities	182

List of Tables

1.1	Network models	19
1.2	Data of the project	24
1.3	Total cost of the project with given decision sets and due date	28
1.4	Probabilities of each outcome	33
1.6	Network reduction employing the topological equation	39
1.7	Ordered triple of probability, time, and cost	40
1.8	Split-logic nodes	43
1.9	Single-unit logic nodes	44
1.10	Types of activities	46
2.1	Data of the project	52
2.2	Different solutions to the linear programming problem	53
2.3	Durations (weeks) and costs (€*10^6) of the project	59
2.4	Solution	63
2.5	Normal time, crash time, normal cost, crash cost and cost of crashing per day	65
2.6	Deviation variables	67
2.7	Tasks to undertake, predecessors, normal and crash duration	70
2.8	Time, cost, quality indicators and weights considered	71
2.9	Optimal solution	72
2.10	Activities to undertake with resources $n = 1$ and $n = 2$	72
3.1	Data of the project	75
3.2	Paths in the network	76
3.3	Random Index (*RI*) for different values of n	78
3.4	Utility values (risk-neutral)	81
3.5	Utility values (risk-aversion) ($U_i = -1.42x^2 + 2.1x + 0.249$)	82
3.6	Utility values (risk-seeking) ($U_i = 1.20x^2 - 0.42x + 0.05$)	82
3.7	Final utility values	82
3.8	Ranking list	83
3.9	Data of the project	87
3.10	Paths in the network	88
3.11	Ideal $\left(A^*\right)$ and negative-ideal $\left(A^-\right)$ solutions	88
3.12	Separation measures (D_j^*, D_j^-) and relative closeness to the ideal solution (C_j^*)	89
3.13	Best (f_i^*) and worst (f_i^-) values of all criterion functions	89

3.14	Values of S_j, R_j, and Q_j	89
3.15	Results obtained by both methods	90
3.16	Linguistic variables for FTNs	96
3.17	Data of the project	96
3.18	Paths in the network	98
3.19	Type of Preference function and threshold values	98
3.20	Values of $\pi(a,b)$	98
3.21	Outgoing and Incoming flow	99
3.22	Net flows	99
4.1	Tasks, predecessors, normal duration and crash time	107
4.2	Coalitions and gains for Paths 1, 2, and 3	108
4.3	Planned time, real time, delays and expeditions	112
4.4	Planned time, real duration, and slacks of the paths	113
4.5	Coalitions, delays (days) and costs associated to each coalition	113
4.6	Tasks to undertake the project	117
4.7	Earliest start, earliest finish, latest start, latest finish and float time	118
4.8	Paths, durations, floats, and coalitions	118
5.1	Computations for $f_3(d_3)$	124
5.2	Computations for $f_2(d_2)$	124
5.3	Computations for $f_1(5)$	126
5.4	Sets of time-cost alternatives ($\langle \text{Time, Cost} \rangle$) for the activities	129
5.5	Set of tuples at the end of stage 1, 2, 3, 4, and 5	130
6.1	Bromilow's, Ireland's, and Chan's time-cost models	135
6.2	Time and cost data obtained from the projects	136
6.3	Tasks to undertake the project, duration and cost	148
6.4	Actual cost, forecasted value and MAPE values	148
6.5	Terms and equations developed for *EV* management	152
7.1	Data of the project	158
7.2	Start and finish times	160
7.3	Relative and cumulative frequency	161
7.4	Adjustment values	168
8.1	Activity durations	177
8.2	Transition matrix for a 4-stage project with each activity duration = 24 days	178
8.3	Transition matrix for a 4-stage project. $T = 2$	179
8.4	Transition matrix for a 4-stage project. $T = 3$	179
8.5	Transition matrix for a 4-stage project. $T = 4$	179
8.6	Transition matrix for a 4-stage project. $T = 9$	180
8.7	Project risk assessment	184

9.1 Variables and unit of measurement 193
9.2 Data for the DEA application 195
9.3 Results for the DEA application 198

此为试读,需要完整PDF请访问: www.ertongbook.com

Introduction

Owing to its societal and economic relevance, Project Management has become an important and relevant discipline and a key concept in modern-world private and public organizations. Project Management is an academic discipline discussed both in Management Science and in Operations Research. Management Science tends to focus on quantitative tools and the soft skills necessary to manage projects successfully. Operations Research gives the essential scientific contribution to the success of Project Management through the development of models and algorithms. The aim of this book is to fill the gap between scientific research and practical application of that research. The chapters explore the use of the existing Management Science models providing valuable tools for the project modelling, evaluation, scheduling, and monitoring.

This book will provide project managers with the tools and methods necessary to make sound decisions in the complex environments that they face today in order to manage projects successfully. With this aim, the book will include numerous examples of these tools for problem-solving applied to Project Management.

What is a Project?

Generally speaking, a project consists of a number of tasks that must be done for the project to be completed. These tasks have durations, they typically cost money, and they often require non-financial limited resources such as people and facilities. They also have precedence relationships which put constraints on what can be done and when.

Following the definition in BS 6079-1 'Guide to Project Management', a project is: 'a unique set of coordinated activities, with definite starting and finishing points, undertaken by an individual or organization to meet specific objectives within defined schedule, cost and performance parameters'. This concept of project implies:

1. The identification of the system to be transformed.

2. The description of the initial state and the final state that should represent the targets of the project.

3. An organizational framework. Projects need the skills and talents from multiple professions and organizations which usually have something at stake, because failure would jeopardize the organization or its goal.

4. A set of resources.

5. A methodological support.

Projects were traditionally the prerogative of the engineering disciplines, but with the dynamics of business, Project Management has moved into business' main street. A project could be the building of a house, a ship, or the development of a software program, and many others actions such as military campaigns or recovery programmes from natural disasters also meet the criteria of projects.

Dimensions of a Project

Typically, projects have three primary objectives: to finish the project quickly, to consume as few resources as possible (especially, to minimize costs), and to produce a high-quality project. In addition, in certain industries like airlines, railways, etc., some people add a fourth dimension – safety – which is considered to be equally important. In today's highly competitive business environment, Project Management's ability to schedule activities and monitor progress within time, cost, and performance guidelines is becoming increasingly important to obtain competitive priorities. This implies that there are trade-offs that must typically be made when scheduling a project.

The usual decision of Project Management focuses primarily on the time dimension. The typical questions in the mind on any project manager that need to be answered are: how long will the project take to complete if everything goes according to schedule? Which tasks form bottlenecks that prevent the project from being completed earlier? And which tasks have some slack in the sense that they can be delayed to some extent without delaying the project?

The second dimension refers to resources. The project must be accomplished within the budgeted cost. The tasks in a project almost always compete for

resources, whether dollar or non-financial resources, and no real Project Management application can afford to ignore these resources. How to spend money optimally in order to speed up the completion of the project is a typical problem in Project Management that requires problem-solving techniques, such as optimization problems, and decision-making, as well as management skills.

The third dimension, scope, is the most difficult to quantify. The project must meet the performance requirements, and scope must include not only quality but also safety or any other performance measurements. The project manager must know what it is intended to do and what features the project should include.

Who is a Project Manager?

A project manager may be defined as that person who has the responsibility, authority, and the necessary management skills to achieve the project objectives within agreed time, cost, and performance criteria. The project manager must be an effective leader that makes all major decisions based on their individual insights and experience. The issues of interest to a project manager may be grouped under four general headings (Elmaghraby, 1995):

1. Representation and modelling for visualization analysis.

2. Scheduling activities subject to resource constraints.

3. Financial issues, either related to project 'compression' or to cash flows.

4. Uncertainty in activity durations as well as in resource availabilities and/or cash flows, and how to cope with it.

What is Project Management?

The definition of Project Management given by the PM book guide (PMI, 2004) can be used as a starting point: 'Project management is the application of knowledge, skills, tools, and techniques to project activities in order to meet or exceed stakeholder needs and expectations from a project.' However, scholars, practitioners, and academic and professional societies have different definitions and interpretations of the subject of Project Management (Kwak

and Anbari, 2009). Behavioural scientists may think of the matrix organization or emotional intelligence; operational researchers may think of network analysis, queuing theory, or optimal plant design; strategic scholars may think of strategic alliances among different organizations during project evaluation.

Project Management is the process of conceiving, designing, preparing, evaluating, scheduling, organizing, monitoring, and controlling the transformation of a system from an initial state, to a specific state, and the motivation of all those involved in it in order to achieve the project objectives within defined schedule, cost, and performance parameters. It is usually admitted that modern Project Management appeared during WWII and was initially dedicated to big military and construction projects. Today, projects seem to have become increasingly common in all kinds of organizations (Mawby and Stupples, 2002). They are increasingly large, complex and constrained, and may involve large numbers of interested parties and professional and technical disciplines. As projects became more and more apparent in organizations, and as they had much larger amounts at stake, it became impossible to sustain them without specific and rigorous methodology. Project Management has then grown up and spread around the world to become what it is today, that is to say, a set of theories, principles, methodologies and practices, sometimes included in standard body of knowledge as Project Management Institute (PMI, 2004) and Association for Project Management (PMA, 2006).

There has been a long debate in the management education community as to whether Project Management is a practice or an academic discipline. In several disciplines such as the Construction, Engineering, and Management disciplines people learn planning, managing, and controlling engineering construction projects to meet the time, budget, and specifications. However, when it comes to the Business and Management discipline, scholars often appear puzzled and unconvinced of the notion of Project Management. Project Management is more applied and interdisciplinary than other management discipline so it is more difficult to justify the field as a distinguishable academic discipline within the academic management community. Kwak and Anbari (2009) identified eight categories that represent the disciplines where one can find Project Management research:

1. Operations Research/Decision Sciences/Operations Management/ Supply Chain Management. This refers to the discipline associated with quantitative decision analysis and management principles including

various optimization tools and techniques, network analysis, resource levelling, simulation, etc.

2. Organizational Behaviour/Human Resources Management. This refers to the discipline associated with organizational structure, organizational dynamics, motivations, leadership, conflict management, etc.

3. Information Technology/Information Systems. This refers to the discipline associated with the use of computers and computer systems to process, transmit, store, and retrieve information for better management decisions.

4. Technology applications/Innovation/New product development/ Research and Development. This refers to the discipline associated with the concepts of making innovative and technological improvements and the research and development of entirely new products, services, and processes.

5. Engineering and Construction/Contracts/Legal aspects/Expert witness. This refers to the discipline associated with the use and application of a broad range of professional expertise to resolve issues related to engineering and construction, contracts, expert witness, and their legal implications.

6. Strategy/Integration/Portfolio Management/Value of Project Management/ Marketing. This refers to the concepts of organizing and managing resources to maximize profit, minimize cost, and support the overall strategy of the organization.

7. Performance Management/Earned Value Management/Project Finance and Accounting. This refers to the concepts and techniques that measure project progress objectively by combining measurements of technical performance, schedule performance, and cost performance.

8. Quality Management/Process Improvement. This refers to the concepts of improving processes, minimizing defects, and reducing costs by implementing continual improvement principles and specific measures and metrics.

In recent years, the range of Project Management applications has greatly expanded. Today project managers have gained recognition and employment

opportunities beyond construction, aerospace, and defence, in pharmaceuticals, information systems, and manufacturing. Project managers are interested in finding out to what extent the Project Management profession would accommodate the needs of any industry. Business organizations are interested in finding out to what extent is the Project Management profession fragmented into industry-specific areas, or to what extent would an academic degree in Project Management accommodate industry-specific needs. Universities and other training institutions are interested in accommodating the needs of both individuals and organizations involved in Project Management.

Following Popper (1972), we reduce the complexity of the world into experiments which may be validated in that they are repeatable and, we build knowledge through regulation of our theories. Management Science, the application of scientific method to management, 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). Significant parts of Project Management can be developed along 'theory' lines with reasonable scientific rigour. There are examples of Project Management benefiting from scientific knowledge such as network scheduling, linear programming, dynamic programming, or Goldratt's theory of constraints. Project Management is a discipline in the sense that there is a substantial and, in places, significant literature on it. There are defined 'Bodies of Knowledge' on it and there are many people who believe that they practise it and professional societies who promote it and who examine and qualify people in it.

Project Management has become a key concept in modern world of private or public organizations which are considered open and complex systems interacting with the environment and pursuing objectives according to their specific mission and nature (Drucker, 1974; Ackoff, 1970; Simon, 1977). The achievement of such objectives implies structuring the activities of the organizations through projects with specific targets that should be consistent with the adopted organizational objectives (Tavares, 2002).

The current vision of Project Management tends to rely upon the notions of planning and control, to propose models and prescriptions as ways to increase the ability of humans to control complex worlds (Stacey, 2001; Wood, 2002). It emphasizes the role of project actors regarding the issues of time, cost, and scope (Cicmil and Hodgson, 2006). The increasing use of computers has given rise to a new generation of operations researchers devoted to computer applications and expert systems for project planning, control, and risk analysis.

此为试读,需要完整PDF请访问: www.ertongbook.com