MEGAPROJECT RISK ANALYSIS AND SIMULATION: A DYNAMIC SYSTEMS APPROACH

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emerald PUBLISHING

United Kingdom – North America – Japan – India – Malaysia – China

Emerald Publishing Limited
Howard House, Wagon Lane, Bingley BD16 1WA, UK

First edition 2017

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

Library of Congress Classification (LCC) – HE1-9990
BIC - KJMP
BISAC - BUS101000
Dewey Decimal Classification (DDC) – 388

ISBN: 978-1-78635-831-8 (Print)
ISBN: 978-1-78635-830-1 (Online)
ISBN: 978-1-78714-301-2 (Epub)

To our families

Contents

Abbreviations

ANP	Analytical Network Process
AHP	Analytic Hierarchical Process
BBS	Bilfinger Berger Civil (UK) and Siemens plc
CEC	City of Edinburgh Council
CDR	Cost of Dispute Resolution
CDUD	Cost of Delay in Utility Diversion
CI	Consistency Index
CLA	Cost of Legal Action
CLD	Causal Loop Diagram
COD	Cost of Delays
COR	Cost of Rework
CR	Consistency Ratio
DEG	De-Escalation to Grievances
Disp.	Disputes
DOAF	Delay of All Forms
DOC	Delay in Obtaining Consent
EC	Economic Certainties
E*c*RM	Economic Risks Model
ETN	Edinburgh Tram Network (Project)
EG	Escalation to Grievances
EnC	Environmental Certainties
EnR	Environmental Risks
EnRE	Environmental Regulation Enforcement
EnRM	Environmental Risks Model
EnU	Environmental Uncertainties
EP	Energy Price
EPC	Engineering, Procurement and Construction
EPCO	Escalation to Project Cost Overrun
EPTO	Escalation to Project Time Overrun

ER	Economic Risks
ERM	Environmental Resource Management
ErG	Error Generation
EU	Economic Uncertainties
FE	Foreign Exchange
GCP	Ground Conditions Problem at a Given Site
GFP	Government Funding Policy
IPV	Ideal Priority Value
LA	Legal Actions
LD	Liquidated Damages
LIR	Local Inflation Rate
LRC	Legislative & Regulation Changes
IRPI	Ideal Synthesized Risk Priority Indexes
IRPV	Ideal Risk Priority Index
MCDM	Multi-Criterion Decision Making
MLDMBI	Multi-Level Decision-Making Bodies Involvement
MP	Material Price
MPDS	Modification to Project Design & Specification
MPH	Material Price Hike
MUDFA	Multi-Utilities Framework Agreement
NPV	Normal Priority Value
O&M	Operations and Maintenance
PA	Social Acceptability
PC	Political Certainties
PDP	Political Debates on the Project
PH	Political Harmony
PI	Political Indecision
PIP	Political Interferences in the Project
PMPS	Pressure to Modify Project Scope
P*o*RM	Political Risks Model
PQD	Project Quality Deficiency
PR	Political Risks
Proj.C	Project Complexity
PS	Political Support

Proj.S	Project Scope
PT	Project Termination
PU	Political Uncertainties
RMSI	Respondent's Mean Scores of Importance
RPCO	Risks of Project Cost Overrun
RPI	Risk Prioritization Index
RPIG	Global Risks Priority Index
RPIL	Local Risk Priority Index
RPTO	Risks of Project Time Overrun
SC	Social Certainties
SD	System dynamics
SFM	Stock and Flow Model
SG	Social Grievances
SI	Social Issues
S*o*RM	Social Risks Model
SPV	Special Purpose Vehicle
SR	Social Risks
SU	Social Uncertainties
TC	Technical Certainties
TDUU	Time to Divert Underground Utilities
T*e*RM	Technical Risks Model
TIE	Transport Initiatives Edinburgh Ltd.
TPAS	Threat to Personal & Asset Security
TPV	Total Priority Value
TR	Technical Risks
TRO	Traffic Regulation Order
TRPI	Total Risk Priority Index
TU	Technical Uncertainties
WCP	Worksite Coordination Problems
WQS	Weighted Quantitative Score
WI	Wage Inflation

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Acknowledgements

This book summarizes a dedicated research funded and conducted under the megaproject management research theme at Heriot-Watt University and in the Scott Sutherland School of Architecture and Built Environment at Robert Gordon University in the United Kingdom. The research was also conducted through collaborative research amongst researchers from 24 European countries inside the COST Action TU1003 MEGAPROJECT (2011–2015), which was funded by the European Cooperation in Science and Technology (COST) and focuses on the effective design and delivery of megaprojects in the European Union. The COST Action on MEGAPROJECT was chaired by Professor Naomi Brookes at the University of Leeds in the United Kingdom.

The authors would like to thank all participants for making time and efforts to support the research through interview and questionnaire survey for data collection from the Edinburgh Tram Network (ETN) project. The authors would also like to thank colleagues at the COST Action TU1003 for their advice and comments on the research into the ETN project. Without their supports, this research cannot be completed.

The research theme on megaproject management at Heriot-Watt University was set up in 2012 and has been strongly supported by the following world renowned experts:

- Geoff Baskir, Chair, Aircraft/Airport Compatibility Committee, Transportation Research Board, National Academy of Sciences, USA
- Naomi Brookes, Professor of Complex Project Management, University of Leeds, and CEO, Projektlernen, UK
- Volker Buscher, Director, Global Digital Business, Arup, UK
- John Connaughton, Professor of Sustainable Construction, Head of Construction Management and Engineering, University of Reading, UK
- Henry Ergas, Professor of Infrastructure Economics, University of Wollongong, Australia
- Stuart Ladds, Head of Property Strategy & Logistics, College of Policing Limited, UK
- Heng Li, Chair Professor in Construction Informatics, The Hong Kong Polytechnic University, Hong Kong, China
- Edward W. Merrow, Founder and President, Independent Project Analysis, Inc., USA

- Stanley G. Mitchell, CEO, Key Facilities Management International, Scotland. Chair, ISO TC 267 Facilities Management Committee
- David Mosey, Professor of Law and Director, Centre of Construction Law and Dispute Resolution, King's College London, UK
- John Pike, Chairman, Bellrock Property Services, UK
- Rodney Turner, Professor of Project Management, SKEMA Business School, France.

The authors would like to thank the entire publishing team at Emerald. Special thanks to colleagues at Emerald Publishing Limited, including Amy Barson, Senior Content Editor; Carole Caines, Books Production Controller; Nicki Dennis, Publisher; Charlotte Hales, Editorial Assistant; Liron Gilenberg, Cover Designer; Philippa Grand, Executive Publisher; Jen McCall, Publisher; and Kousalya Krishnamoorthy, Project Manager at MPS Limited.

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Preface

This book provides technical details on a dynamic systems approach to megaproject risk analysis and simulation, and it is based on the authors' long-term research into megaproject management, multi-criteria decision making, and system dynamics. For the first time, the authors have attempted to find a technical solution to tackle overruns on cost and time in megaprojects, and this is based on a comprehensive set of risks associated with social, technical, economic, environmental and political (STEEP) issues in megaproject environment and a dynamic systems approach called SDANP. The approach is an integrated use of tools including analytic network process (ANP) and system dynamics (SD) for risks prioritization and simulation.

The new SDANP model is described in this book with a case study on the Edinburgh Tram Network (ETN) project, which was a live case project during the time of the authors' research into a dynamic systems approach to megaproject risk analysis and simulation. Through this experimental research, the SDANP model has provided interesting results on cost and time overruns with accuracy rates above 80%, respectively, for the ETN project over the time period between 2007 and 2013. The authors expect that this dynamic systems approach to megaproject risk analysis and simulation can be widely tested for the benefits of stakeholders in dealing with cost and time overruns in megaproject development.

Prince Boateng
Zhen Chen
Stephen O. Ogunlana

Foreword

As our journey into the uncertainties of the twenty-first century continues, of one thing we can be sure: megaprojects are viewed as increasingly important in creating solutions to societal problems. Megaprojects will provide the new power plants that will give us with green energy, they will deliver transport systems that work for all without increasing carbon emissions, they will provide us with the integrated hospitals and healthcare that we need and they will even delight us with cultural and sporting events! We remain optimistic that the huge complexities of megaprojects in people, capital and technology can be tamed and we can look forward to feeling the benefits of their successful implementations.

However, at their heart, megaprojects pose a conundrum. Time after time (and despite their apparent benefits) we do not seem to be able to deliver them on time, to budget and actually producing the output functionality that we need. We only have vague ideas why some succeed and, where they fail, we discover worryingly psychological failings in their planning and design. Given their importance in facing twenty-first century challenges, we desperately need to undertake more research to help us deliver megaprojects more effectively and to insure that the results of that research are available to the widest possible population of stakeholders.

It is precisely this gap that Boateng, Chen and Ogunlana have aimed at with the work that they report upon in this book. They take one of the most clearly identified complexities in delivering megaproject, namely risk, and explore new ways of conceptualizing it and dealing with it. They employ a wide range of novel systems dynamics and frameworks to develop an understanding of risk in megaprojects. They provide interesting applications of techniques used elsewhere in simulation to megaprojects. They illustrate their work with an insightful case of the Edinburgh Tram Project, a megaproject which embodies both the huge benefits that megaprojects can bring and the significant issues that inhibit their delivery. Boateng, Chen and Ogunlana are to be congratulated for the zeal with which they have pursued their research objectives and their fervour to share the results of their endeavours with others.

This book provides a valuable addition to the work currently being undertaken by academics and practitioners alike in understanding megaproject design and delivery. It is through such committed work that we really will be able to tame megaprojects and insure that they can reliably deliver the outcomes that society so desperately needs.

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Chapter 1

Introduction

1.1. Introduction

Major stakeholders on megaprojects have been facing risks associated with social, technical, economic, environmental and political (STEEP) issues that may lead to significant cost and time overruns compared with initial budget and schedule estimates. Although much attention has been devoted to managing risks in megaproject delivery, results have not always been satisfactory in most cases across the world in the past. There have been increasing needs for advanced tools to support better risk assessment so as to inform decision-making in megaproject management. Regarding the complexity of megaprojects, and the great scope for risks and their interaction in mega construction and development projects, it has been widely accepted that quantitative approaches are necessary supplements in risk analysis process. However, there has been little attempt to apply sophisticated methods recommended by industry standards for risk analysis in megaproject practice. Through developing and using a dynamic systems approach over a four-year period, the authors of the book have developed a new tool that can significantly identify major project risk factors and provide predications on time and cost overruns with over 80% accuracy compared to real figures in one megaproject, that is the Edinburgh Tram Network (ETN) project. This book summarizes their research into megaproject risk analysis and simulation to inform both academic researchers and megaproject stakeholders who have interest in qualitative and quantitative risk analysis and simulation for megaprojects across the world.

This book covers all aspects of a real case study oriented research into megaproject risk analysis and simulation through a dynamic systems approach. A case study on the ETN project is used as an example of megaproject to develop a general technical framework called SDANP for STEEP risks analysis and simulation on megaprojects. An analytic network process (ANP) is adopted for risk quantification modelling, while a system dynamics (SD) (Brookes, 2015; Dimitriou, 2014; Flyvbjerg, 2014;

Flyvbjerg, Bruzelius, & Rothengatter, 2003; Mentis, 2015; Priemus, 2014; Renuka, Umarani, & Kamal, 2014; Spirkova, 2014; Van de Graaf & Sovacool, 2014) for risk simulation over time. Both the ANP and SD provide practical guides for the application of the dynamic systems approach in megaproject research and practice.

By providing crucial background information for those who want to understand the dynamics of risks over time and their assessment during the decision-making processes on large transport infrastructure projects (Hickman et al., 2015), this book can prove an important source of information for academics, researchers and students in the fields of transport, infrastructure, project management, management science, economic analysis (cost−benefit analysis), public policy, environmental policy and ethics. Practitioners, politicians and policy-makers involved in large transport infrastructure projects can also find this book to be a useful reference on risk analysis and simulation for megaproject management.

1.2. The Problem with Megaprojects

1.2.1. Megaproject Risks

Flyvbjerg, Skamris Holm, and Buhl (2003) found that 258 highway and rail projects ($90 billion worth) in 20 countries did not perform well on budgets as estimated, and about 90% of these projects suffered cost overruns, with the average rail project costing 45% more than what were projected, while it was over 20% in average for highway projects. Based on a continuous research, Flyvbjerg et al. (2003) underscored that cost overrun has not decreased over 70 years in the 20th century and seems to be a global phenomenon, which can also be attested on many megaprojects. For example, the Pusan and Muckho harbour project suffered significant cost overruns in the mid-1970s and relied on an extra $75 million loan for it to complete (2003), and the Big Dig project was estimated at a cost of $2.6 billion but was completed at a cost of $14.6 billion, additionally completion was delayed from 2002 to 2005 (2003). These projects have made the learned society and the public acutely aware of the problems of project delay and cost overruns in megaprojects. In addition, these technical problems also indicate clearly that construction cost estimating on major infrastructure projects has not improved in accuracy in the past more than half century, and the magnitude of underestimated project costs has been almost in the same order according to Flyvbjerg, Holm, and Buhl (2002) and Salling and Leleur (2015). It has been identified by Flyvbjerg et al. (2002) that the main possible reason for cost and time overruns in many megaprojects across the world was to simplify the marginalization of risks during feasibility studies by undependably assuming what the World Bank calls the 'Everything Goes According to Plan' (EGAP) principle. There have been increasing needs for new ideas and techniques (Davies, MacAulay, DeBarro, & Thurston, 2014; Flyvbjerg et al., 2002; Kwak, Walewski, Sleeper, & Sadatsafavi, 2014) in order to tackle all risks associated with those significant problems for making the right decisions (Mentis, 2015) on both business and project towards successful megaprojects.

Evidence gleaned through research worldwide suggests that large and complex infrastructure projects such as airport, bridge and highway are usually money pits where funds are simply 'swallowed up' without delivering sufficient returns. These problems are as a result of unbalanced subjective beliefs and information in assessing risks and uncertainties, and taking corrective actions to effectively control and manage the identified risks at the right time (Brookes, 2015; Dimitriou, 2014; Flyvbjerg, 2014; Flyvbjerg et al., 2003; Mentis, 2015; Priemus, 2014; Renuka et al., 2014; Spirkova, 2014; Van de Graaf & Sovacool, 2014). Flyvbjerg, (2014) further asserts that the track record of megaprojects under his study was terrible during developmental phases and reflected many credibility problems especially on transportation megaprojects. Proost et al. (2014) and Salling and Leleur (2015) emphasised that costs for transportation megaprojects were often grossly underestimated while traffic is often overestimated, and the perceived failure of the project was subject to a public enquiry, which concluded that the planned budget and schedule were hardly realistic although some of the cost increases were justified spending indeed. In reality, significant wastes were caused by design delays, over-optimistic programming and uncertain authority at the construction and development stages of megaprojects.

The construction industry, like many other industries is a free-enterprise system, and has sizeable risks built into its structure and project based processes (Ball, 2014; Fulford & Standing, 2014; Guo, Chang-Richards, Wilkinson, & Li, 2014). From the initiation to the closing stages, construction process especially that for megaprojects is complex and characterized by a number of uncertainties and interactions (Brookes, 2015) that can negatively influence the project delivery in many ways (Brookes, 2015; Dimitriou, 2014; Flyvbjerg, 2014; Flyvbjerg et al., 2003; Mentis, 2015; Priemus, 2014; Renuka et al., 2014; Spirkova, 2014; Van de Graaf & Sovacool, 2014). For example, uncertainties about changes in weather conditions (Mentis, 2015), sub-contractor delays (Diab & Nassar, 2012; Eizakshiri, Chan, & Emsley, 2015), community resistance (Jordhus-Lier, 2015), political interferences (Kennedy, 2015) and unpredictable site conditions (Adam, Josephson, & Lindahl, 2014; Boateng, Chen, & Ogunlana, 2012) can compromise the completion of megaproject development on time