

David C. Wynn  
Matthias Kreimeyer  
Katharina Eben  
Maik Maurer  
Udo Lindemann  
John Clarkson  
(eds.)

# Managing Complexity by Modelling Dependencies

Proceedings of the 12th International DSM Conference  
Cambridge, UK, 22–23 July 2010



UNIVERSITY OF  
CAMBRIDGE

Engineering  
Design  
Centre



Product Development

HANSER

Wynn, Kreimeyer, Eben, Maurer, Lindemann, Clarkson  
**Proceedings of the 12th International DSM Conference**

David C. Wynn  
Matthias Kreimeyer  
Katharina Eben  
Maik Maurer  
Udo Lindemann  
John Clarkson  
(eds.)

# **Managing Complexity by Modelling Dependencies**

Proceedings of the 12th International DSM Conference  
Cambridge, UK, 22–23 July 2010

HANSER

*The Editors:*

David C. Wynn  
Matthias Kreimeyer  
Katharina Eben  
Maik Maurer  
Udo Lindemann  
John Clarkson

Distributed by  
Carl Hanser Verlag  
Postfach 86 04 20, 81631 Munich, Germany  
Fax: +49 (89) 98 48 09  
www.hanser.de

The use of general descriptive names, trademarks, etc., in this publication, even if the former are not especially identified, is not to be taken as a sign that such names, as understood by the Trade Marks and Merchandise Marks Act, may accordingly be used freely by anyone. While the advice and information in this book are believed to be true and accurate at the date of going to press, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

**Bibliografische Information Der Deutschen Bibliothek**

Die Deutsche Bibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über <<http://dnb.d-nb.de>> abrufbar.

ISBN 978-3-446-42473-9

All rights reserved. No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying or by any information storage and retrieval system, without permission in writing from the publisher.

© Carl Hanser Verlag, Munich 2010  
Production Management: Steffen Jörg  
Typsetting: Karada Publishing Services  
Coverconcept & -design: Atelier Frank Wohlgemuth, Bremen  
Printed and bound by Digital Print Group O. Schimek GmbH, Munich  
Printed in Germany

# TABLE OF CONTENTS

Foreword	ix
Review Committee	xi
<b>Part I: Risk and Decisions</b>	
Dependency Structure Matrix Modelling for Stakeholder Value Networks <i>Wen Feng, Edward F. Crawley, Olivier de Weck, Rene Keller and Bob Robinson</i>	3
Using DSM Approach to Manage Interactions between Project Risks <i>Franck Marle</i>	17
Modelling Risk Interactions to Re-Evaluate Risks in Project Management <i>Chao Fang, Franck Marle and Ludovic-Alexandre Vidal</i>	31
Analysis of Decision-Making Processes in the Development of Complex Solutions <i>Sebastian Lederer, Franck Marle, Clemens Hepperle and Udo Lindemann</i>	45
<b>Part II: Planning</b>	
Analysing Plan Content Using a Matrix-Based Approach <i>Mark P. De Lessio, Nicholas H.M. Caldwell, David C. Wynn and P. John Clarkson</i>	57
Practical Ways of Dealing with Progress in a DSM Tool <i>Paul Waskett, Andrew Newton, John Steele and Jamie Hammond</i>	71
Planning Support of Initial Design Process Based on Grouping and Ordering of Tasks: Design Example of an Integrated Circuit <i>Akihiro Hirao, Tsuyoshi Koga and Kazuhiro Aoyama</i>	83
PEM – A New Matrix Method for Supporting the Logic Planning of Software Development Projects <i>Zsolt Tibor Koszty 'n and Judit Kiss</i>	97
<b>Part III: Iteration Management</b>	
Modelling the Influence of Uncertainty, Process Architecture and Feedback Dynamics on PD Projects <i>H. Nam Le, David C. Wynn and P. John Clarkson</i>	113
Using MDM-Methods in Order to Improve Managing of Iterations in Design Processes <i>Sebastian Kortler, Bergen Helms, Marina Berkovich, Udo Lindemann, Kristina Shea, Jan Marco Leimeister and Helmut Krcmar</i>	125

Sufficiency Condition for Stability of a Fully Coupled Design Process 139  
*Zheng Wang and Christopher L. Magee*

MDM as a Process Mapping Tool in Lean Construction 153  
*Fabian Furtmeier, Martin Graebisch, Fatos Elezi, Iris D. Tommelein and Udo Lindemann*

#### **Part IV: Products and Architectures**

Development of Modular Product Families 169  
*Christoph Blees, Hendry Jonas and Dieter Kraus*

A Framework for Evaluating Product Architecture of Automation Production Facilities 183  
*Maximilian P. Kissel, Katharina G.M. Eben, Steven Braun, Jakob Schmidt-Colinet, Martin Obermeier, Udo Lindemann and Birgit Vogel-Heuser*

Comparing Matrix-Based and Graph-Based Representations for Product Design 195  
*Andrew H. Tilstra, Matthew I. Campbell, Kristin L. Wood and Carolyn C. Seepersad*

Function-Based Contact and Channel-Modelling in the Development of an Innovative Car 207  
*Albert Albers and Andreas Braun*

Using an Enrich Semantic in Design Structure Matrix (DSM) to Generate Less Uncertain Concepts 221  
*Vincent Holley, Bernard Yannou and Marija Jankovic*

#### **Part V: Requirements, Reviews and Change Management**

DSM Based Approach for Managing Requirements, Rules and Design Parameters in Knowledge Based Design Process 237  
*Sreeram Bhaskara*

Structural Analysis of Requirements – Interpretation of Structural Criteria 249  
*Katharina G.M. Eben and Udo Lindemann*

Using Connectivity Models to Support Design Reviews 263  
*Owolabi Ariyo, Peter Heisig, P. Andrew Wilson, Matthew Harnden and John Clarkson*

Path-Based and Pattern-Based Approaches for Change Management 279  
*Simon Li and Elmira Rajinia*

The Impact of Packaging Interdependent Change Requests on Project Lead Time 293  
*Naveed Ahmad, David C. Wynn and John Clarkson*

#### **Part VI: Developments in DSM and MDM Theory**

Reducing Data Acquisition Effort by Hierarchical System Modelling 309  
*Wieland Biedermann, Ben Strelkow, Florian Karl, Udo Lindemann and Michael F. Zaeh*

Multi-Domain DSM: Simultaneous Optimization of Product, Process & People DSMs 319  
*Ali A. Yassine*

Approach towards a More Flexible Handling of Domains in Complex Systems <i>Andreas Kohn and Udo Lindemann</i>	333
Efficiently Computing with Design Structure Matrices <i>Shahadat Hossain</i>	345
<b>Part VII: Dependency Modelling in Construction</b>	
Lessons from Japan: A Look at Century Housing System <i>Robert Schmidt III, Toru Eguchi and Simon Austin</i>	361
Matrix-Based Change Management: A Case Study in a Construction Project <i>Jian Jun Chen and Simon Li</i>	375
The Complementary Use of the Parameter-Based Design Structure Matrix and the IFC Process Models for Integration in the Construction Industry <i>Sule Tasli Pektas</i>	389
<b>Part VIII: Industry Applications</b>	
The Use of DSM and DMM to Support SAE ARP-4754 Development Activities <i>Marcelo José Ruv Lemes and João Batista Camargo Jr.</i>	405
Exploring DSM to Support Systems Engineering of Composable Simulation Environments <i>Ric Roca</i>	419
Modelling Decision and Data Dependencies in Engineer-to-Order Project Management <i>Marc Zolghadri, Claudia Eckert and Rahi Rasoulifar</i>	433
DSM-Directed Chip Design and Verification <i>Paschal Minogue</i>	447
Author Index	461
Keyword Index	463

## FOREWORD

The world is growing ever more complex and interconnected. Increasing levels of dependency are making complex systems – such as products, processes and organisations – more difficult to understand, design, optimise and operate. Increases in connectivity are also making some systems more susceptible to uncertainty and change. In many domains and industries there is thus a pressing need to improve the capacity of complex systems to deliver desired levels of performance in terms of time, cost, quality, operational efficiency and many other criteria; and to make these systems robust to uncertainties as well as more flexible to respond to emerging opportunities. Satisfying these many requirements requires systems with appropriate levels of complexity, and therefore necessitates tools and techniques for delivering and managing that complexity.

Dependency and Structure Modelling (DSM) techniques support the management of complexity by focusing attention on the elements of a complex system and the dependencies through which those elements are related. By highlighting the dependency structures in systems and their environments, and by helping to understand the implications of connectivity on different aspects of system performance, the DSM perspective can assist in understanding, designing, optimising and maintaining complex systems; including products, processes and organisations.

This volume contains 33 peer-reviewed papers describing the state-of-the-art in DSM research and applications. The papers were presented at the 12<sup>th</sup> International DSM Conference held in Cambridge, UK in July 2010. They advance DSM thinking and practice in many areas: risk and decisions; planning; iteration management; products and architectures; requirements, reviews and change management; developments in DSM and MDM theory; DSM in construction; and industry applications.

Regular attendees of the DSM conference series will have noticed that a number of changes to the format have been introduced in 2010. The first is a change in name; although the conference has always been known as *The International DSM Conference*, this year the acronym abbreviates *Dependency and Structure Modelling* rather than *Design Structure Matrix*. This change reflects a gradual shift in emphasis of papers presented at the conference series. In recent years, the initial focus on design structure matrix-based modelling techniques has expanded and papers have encompassed a broader range of modelling and visualisation approaches, including multiple domain matrices, force-directed layouts, and other tools for the representation, visualisation and analysis of dependency structures. Nevertheless, the focus of the conference, and of the papers in this volume, remains on modelling the connections between elements in a system – and on exploring how an understanding of structural dependencies can support the management of complexity by assisting system analysis, design and optimisation.

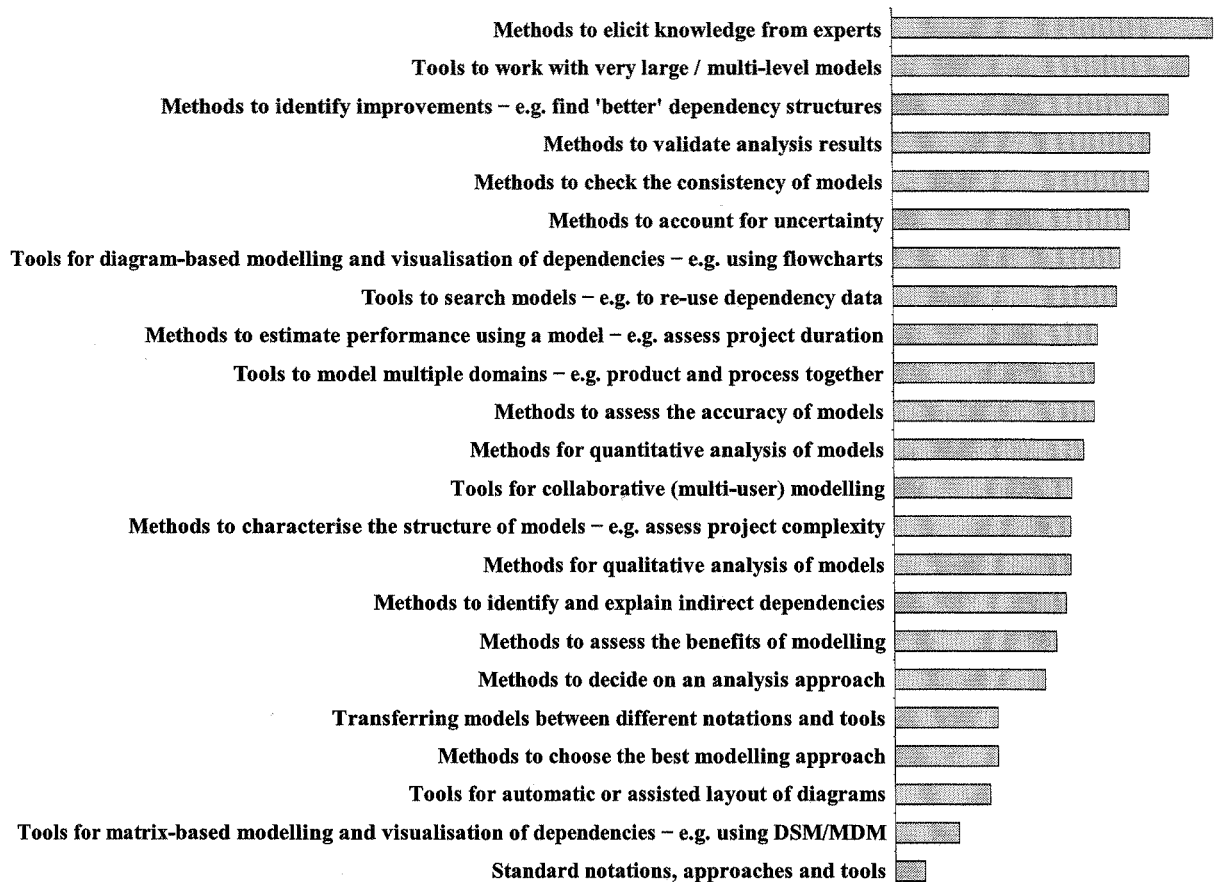
The second change in format has been the increase in length of the papers. In previous years, papers were limited to three pages in length. This year, an allocation of six pages has allowed authors to expand upon their ideas, approaches and tools in greater detail. This was supported by a review process in which most contributions were peer-reviewed by at least two members of the scientific committee and by at least one other peer-reviewer drawn from the pool of authors.

One of the special features of the DSM conference series has always been a strong emphasis on the exchange of views and ideas between researchers and practitioners. This is reflected in the present volume by a number of papers with industry authors or co-authors, and by the contributions of industry practitioners to the scientific, organising and review committees. With this focus in mind, as part of the conference preparations we undertook to identify DSM research trends and future topics which could enhance the applicability of modelling techniques in practice. Academics and industrialists who had participated in real-life dependency modelling projects were therefore asked to participate in a survey, including all registrants for the DSM 2010 conference. At the time of writing, 37 respondents from 10 countries have completed the survey. Each respondent described in detail their experience of at least one dependency modelling project. These modelling projects used a wide range



of approaches, notations and tools and were undertaken in many different industries. The models were reported to vary in size, comprising just over 195 elements on average (to calculate this average, we first removed one 'outlier' describing a model with 1,000,000 elements). Most respondents were academics in the modelling/DSM community with a background in industry, or industrialists with a background in modelling/DSM research.

Two of the questions in this survey listed a number of topics related to dependency and structure modelling and asked: *How important is it to improve this aspect of dependency modelling?* Respondents were able to indicate their answers on a scale of 1-10 in each case. The average response to this question is shown below, scaled to highlight the trend between minimum and maximum values.



Our interpretation of these results is that topics such as standard notations, DSM tool support and the identification and explanation of indirect dependencies are now considered relatively mature by the respondents. The results suggest that some of the most pressing issues facing dependency modellers in practice surround population and validation of models: how to elicit knowledge from experts; how to deal with very large and multi-level models; how to account for uncertainty; and how to validate analysis results. The community seems to agree that these are hot topics for future research!

We are very pleased to welcome you to the 12<sup>th</sup> International DSM Conference.

David Wynn	<i>University of Cambridge</i>
Matthias Kreimeyer	<i>MAN Nutzfahrzeuge AG</i>
Katharina Eben	<i>Technische Universität München</i>
Maik Maurer	<i>Teseon GmbH, Technische Universität München</i>
Udo Lindemann	<i>Technische Universität München</i>
John Clarkson	<i>University of Cambridge</i>

**The Organising Committee**

# REVIEW COMMITTEE

## SCIENTIFIC COMMITTEE

Austin	Simon
Bonjour	Eric
Braha	Dan
Browning	Tyson
Clarkson	John
Danilovic	Mike
Deubzer	Frank
Eben	Katharina
Eckert	Claudia
Eppinger	Steven
Fadel	Georges
Kreimeyer	Matthias
Lindemann	Udo
Maurer	Maik
Mocko	Gregory
Mostashari	Ali
Stuffer	Rupert
Summers	Joshua
Varghese	Koshy
Waldman	Frank
Whitney	Dan
Wynn	David
Yassine	Ali

## OTHER PEER-REVIEWERS

Ahmad	Naveed
Ariyo	Labi
Bhaskara	Sreeram
Biedermann	Wieland
Blees	Christoph
Braun	Andreas
Elezi	Fatos
Fang	Chao
Feng	Wen
Graebisch	Martin
Heisig	Peter
Holley	Vincent
Hossain	Shahadat
Keller	Rene
Kerley	Warren
Kiss	Judit
Koga	Tsuyoshi
Kohn	Andreas
Kortler	Sebastian
Le	Hoang Nam
Lederer	Sebastian
Lemes	Marcelo Jose Ruv
Li	Simon
Marle	Franck
Minogue	Paschal
Pektas	Sule Tasli
Rizzuti	Sergio
Roca	Ric
Schmidt III	Robert
Stegemann	Patrick
Steward	Donald V
Stowe	Harold
Tilstra	Andrew H
Uzzell	Kimberly Anne
Wang	Zheng
Waskett	Paul Richard
Wiebel	Marion
Zolghadri	Marc