

Yuri Merkuriev
Galina Merkurieva
Miquel Àngel Piera
Antoni Guasch
Editors

Simulation-Based Case Studies in Logistics

Education and Applied Research

 Springer

Yuri Merkuryev
Galina Merkuryeva
Miquel Àngel Piera
Antoni Guasch
Editors

Simulation-Based Case Studies in Logistics

Education and Applied Research

 Springer

Simulation-Based Case Studies in Logistics

Yuri Merkuryev • Galina Merkuryeva
Miquel Àngel Piera • Antoni Guasch
Editors

Simulation-Based Case Studies in Logistics

Education and Applied Research

Yuri Merkurjev, Dr. habil. sc. ing
Galina Merkurjeva, PhD, DSc
Department of Modelling and Simulation
Riga Technical University
Kalku Street 1
LV-1658 Riga
Latvia

Antoni Guasch, PhD
Escola Tècnica Superior d'Enginyeria
Industrial i Aeronàutica de Terrassa
(ETSEIAT)
Universitat Politècnica de Catalunya
Planta 2, C/Gran Capità, 2-4
08034 Barcelona
Spain

Miquel Àngel Piera, PhD
Escola Tècnica Superior d'Enginyeria
Departamento de Telecomunicació e
Ingeniería de Sistemas
Universidad Autónoma de Barcelona
Edifici Q, Campus de la UAB, Bellaterra
08193 Barcelona
Spain

ISBN 978-1-84882-186-6

e-ISBN 978-1-84882-187-3

DOI 10.1007/978-1-84882-187-3

A catalogue record for this book is available from the British Library

Library of Congress Control Number: 2008937461

© 2009 Springer-Verlag London Limited

ARENA is a registered trademark of Rockwell Automation, Inc., Building 2, 2000 Ericsson Drive, Warrendale, PA, 15086, USA, www.rockwellautomation.com

Excel is a registered trademark of the Microsoft Corporation, One Microsoft Way, Redmond, WA 98052, USA, www.microsoft.com

SimRunner is a registered trademark of the ProModel Corporation, 556 East Technology Ave., Orem, UT 84097, USA, www.promodel.com

Apart from any fair dealing for the purposes of research or private study, or criticism or review, as permitted under the Copyright, Designs and Patents Act 1988, this publication may only be reproduced, stored or transmitted, in any form or by any means, with the prior permission in writing of the publishers, or in the case of reprographic reproduction in accordance with the terms of licences issued by the Copyright Licensing Agency. Enquiries concerning reproduction outside those terms should be sent to the publishers.

The use of registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant laws and regulations and therefore free for general use.

The publisher makes no representation, express or implied, with regard to the accuracy of the information contained in this book and cannot accept any legal responsibility or liability for any errors or omissions that may be made.

Cover design: eStudio Calamar S.L., Girona, Spain

Printed on acid-free paper

9 8 7 6 5 4 3 2 1

springer.com

To our daughter Lena and parents
Yuri Merkuryev and Galina Merkuryeva

To my wife Gemma, children Alba, Judit and Marc,
parents Josep M^a and M^a Carmen and godsons Andreu
and Gabriel
Miquel Àngel Piera

To my wife Maria Casadewall and children Alba,
Andreu and Guillem Guash
Antoni Guasch

Preface

Wide global market industry competition and customer product quality requirements are key factors that have forced engineers and economists to improve their operational decisions by integrating production, transport and service operations.

A common logistics perspective dealing with a proper coordination of all material movements and processing activities drives the reader through different chapters of this book. The specific application areas, in which simulation techniques are applied, demonstrate that improving key performance indicators of a real system requires not only addressing its technical aspects, but also designing tactical and operating procedures that would provide both the operational efficiency and economical practicality.

Simulation models have proved to be useful for examining the performance of different system configurations and/or alternative operating procedures for complex logistic and manufacturing systems. It is widely acknowledged that simulation is a powerful computer-based tool enabling decision-makers in business and industry to improve their organisational and operational efficiency. However, several limitations appear when trying to find a feasible solution to a logistic problem as only a limited number of simulation scenarios can be evaluated within acceptable time constraints.

The book is intended for intensive learning about the application of simulation as a decision support tool to tackle complex logistic problems. Case studies in the book are intended to allow the reader to follow and integrate typical phases and activities of a simulation-based study that lead to problem solving. A short list of such typical phases includes: problem formulation and setting of objectives; model conceptualisation; data acquisition and formalisation; simulation model development, verification and validation; experimentation; analysis of simulation output and making conclusions.

A key aspect to succeeding with the use of simulation techniques is the modelling activities. It should be noted that while most industrial operational procedures are based on the extension of current and past operating practices, development of simulation models could support defining new operational procedures at a fundamental level. Simulation allows identifying the role and operating methods of all members that interact during operational activities, as well as understanding the propagation of consequences of any potential decision, in order to deal with a safe and economically viable system.

There are different methodologies that have been used traditionally to develop simulation models in different areas, but modelling of logistic systems cannot be

considered as a pure science. Representation of a logistic system depends on the experience of the modeller to identify a proper abstraction level at which system dynamics should be described, a formalism to be used in order to specify the system, and the clarity to discern between what is important and what can be neglected in the model to satisfy the goal of simulation experiments.

The book describes and illustrates different approaches to developing simulation models at the right abstraction level to be used efficiently by engineers when dealing with strategic, tactical or operational decisions in logistic systems. The book presents 12 simulation-based case studies based on results of the applied research performed by the authors.

These case studies cover a wide range of topics under a common objective, i.e. providing decision support for increasingly complex problems in the logistic area. They address core characteristics of typical logistic problems which can have different characteristics viewed from different perspectives.

While the case studies in this book share some commonality, they certainly make unique contributions in the following three main areas:

Manufacturing and Service Systems:

- *Manufacturing System Planning and Scheduling*, by Merkurjeva and Shires, tackles a very challenging subject regarding the use of simulation models for tuning quickly, and at a very low cost, production schedulers to find optimal configurations of their rules and parameters. Modular simulation models of the entire business/manufacturing system and a production anodising stage sub-model are developed in the ProModel software in order to test off-line effects of various scheduler configurations, avoiding disturbance of a real production process.
- *Hospital Resource Management*, by Aguilar, Castilla and Muñoz, proposes a hospital management tool to improve hospital efficiency by using a simulation model as a key source to obtaining a deeper knowledge on logistic processes and supporting decision making on resource redistribution. The Java discrete-event simulation system SIGHOS is developed and used to analyse different scenarios, providing a better resource distribution according to a priori knowledge of effects that management decisions would have throughout the hospital.
- *Flexible Manufacturing Systems*, by Piera, Narciso and Buil, illustrates advantages of using the coloured Petri net formalism to specify conceptual models of flexible manufacturing systems. The authors pay special attention to explaining how to develop a decision support system that evaluates the whole search space to tackle true flexibility of production systems by means of simulation.
- *Warehouse Order Picking Process*, by Merkurjev, Merkurjeva and Burinskiene, provides an MS Excel-based simulation model developed in order to analyse the influence of routing methods on picker travel distance in a wide-aisle warehouse. The picking process is a critical supply chain component for many companies. Proper warehouse configuration, storage policy, tray replenishment policy, and

other factors are important not only to reduce the delivery time, but also increase productivity while maintaining quality factors at competitive costs. This chapter focuses on a challenging simulation-based optimisation problem of finding appropriate routing methods to minimise the picker travel distance.

Transport Systems:

- *Factory Railway System*, by Guasch, Figueras and Fonseca, focuses explicitly on the analysis of a factory railway system using a simulation model to identify current limitations and potential infrastructure and resource investments to cope with a major increase in production. The conceptual model is formalised in the coloured Petri net formalism and the simulation model is developed in Arena®.
- *Material Handling System*, by Neumann, introduces a simple but efficient model to analyse the performance of a material handling system and to understand the load limit of a real system that consists of a warehouse, production and order-picking areas, and to analyse its ability to cope with a future load. The problem is characterised by numerous crossing flows of palletised raw materials, products and packaging material. The conceptual model is developed in the DOSIMIS-3 simulation package.
- *Vessel Traffic in the Strait of Istanbul*, by Ulusçu, Özbaş, Altıok, Or and Almaz, describes experiences of the authors in the decision-making area by modelling the complexity of operations in the Strait of Istanbul. The simulation model is developed in Arena® and incorporates an algorithm to schedule vessel entrances to the strait. The strait traffic rules and regulations, and transit vessel profiles, along with local traffic and other vessels, pilotage and tugboat services, and meteorological and geographical conditions are modelled, thus providing a tool to analyse policies and decisions regarding management of traffic, risks and vessel delays.
- *Airport Logistics Operations*, by Piera, Robayna and Ramos, introduces a discrete-event system approach to describe the main actors that operate in an airport. Illustrative examples of short-term solutions to mitigate delay propagation in Palma de Mallorca Airport are presented. An Arena® simulation model, describing the main airport operations, demonstrates benefits and handicaps of oversizing pushback resources with respect to improving collaborative decisions.

Supply Chain:

- *Supply Chain Dynamics*, by Hennet, examines the influence of different policies on management of a virtual enterprise in order to satisfy consumers' needs in the most efficient and profitable way, while avoiding the well-known 'bullwhip effect'. An algebraic model is introduced that allows one to compare production

and ordering policies such as an inventory-based policy, an order-based policy and a mean demand-driven policy.

- *Pharmaceutical Distribution Network*, by Van Landeghem, tackles a challenging problem of optimising transportation modes in a distribution network of pharmaceutical goods, where delivery times are critical quality factors, and transport savings compete with the cost of opening and running warehouses.
- *Supply Chain Cyclic Planning and Optimisation*, by Merkuryeva and Napalkova, tackles a very challenging multi-objective stochastic optimisation problem: multi-echelon supply chain planning. It is characterised by a large number of decision variables and conflicting objectives. Several simulation optimisation scenarios are introduced in order to analyse and compare abilities of different optimisation methods and tools. In particular, the SimRunner® and OptQuest® add-on optimisation software and a hybrid simulation optimisation algorithm and tool introduced by the authors illustrate experimentation scenarios under specific cyclical constraints.
- Finally, *Fresh-Food Supply Chain*, by Bruzzone, Massei and Bocca, tackles a difficult problem of modelling fresh-food supply chains considering all the inter-related constraints and variables: time-to-market, traceability, transport/storage conditions, handling, production/process control, demand variability and seasonal behaviours.

Riga, Latvia – Barcelona, Spain
August 2008

Yuri Merkuryev
Galina Merkuryeva
Miquel Àngel Piera
Antoni Guasch

Acknowledgements

This case study book owes its appearance to the simulation community: academicians, researchers and industrial users that are permanently contributing to extending the use of simulation as an efficient tool to improve performance of complex logistic systems.

The origins of the book are traced to a joint work meeting of the McLeod Institute of Simulation Sciences (MISS, <http://www.simulationscience.org>) that took place at the Universitat Autònoma de Barcelona. We sincerely appreciate many public and private institutions and organisations that have indirectly contributed to supporting the scientific collaboration between the editors and authors. Special thanks to Riga Technical University, Universitat Politècnica de Catalunya, Universitat Autònoma de Barcelona, the International Mediterranean and Latin America Council of Simulation (I_M_CS, <http://www.i-m-cs.org>), and The Society for Modeling and Simulation International (SCS, <http://www.scs.org>), which supports many activities in the simulation area worldwide. In particular we express our recognition of the efforts of the organisers and participants of the annual International Mediterranean Modelling Multiconference (I3M, <http://www.liophant.org/i3m/>), which creates a real framework to exchange information, knowledge and experience acquired by top experts in the areas of logistics and simulation.

The editors would like to thank the anonymous reviewers of the book; it has greatly benefited from their very valued comments and suggestions.

We are very grateful to Olesya Vecherinska, Liana Napalkova and Tatyana Lagzdina of Riga Technical University for their accurate typing and formatting with numerous revisions.

Finally, let us wish that this book will become the seed for a series of case study books in the simulation area.

Contents

1	Factory Railway System	1
	<i>A. Guasch, J. Figueras and P. Fonseca</i>	
1.1	Introduction	1
1.2	Aims of the Study	2
1.3	Description of the System	2
1.3.1	The Factory	2
1.3.2	Arrivals of Hot Coils	3
1.3.3	Hot-Coil Consumption	5
1.3.4	Railway System and Storage Operations	6
1.4	Modelling Methodology	7
1.5	Conceptual Model Building, Coding and Verification	8
1.5.1	Arrivals of Hot Coils	8
1.5.2	Storage Areas and Unloading of Ships and External Trains	9
1.5.3	Pickling Line	10
1.5.4	Scheduling	10
1.6	Experimentation	12
1.6.1	Initial Scenario	13
1.6.2	Second Scenario: Dampen the Harbour Arrival Peaks Using A1	14
1.6.3	Third Scenario: Dampen the Arrival Peaks and Use Storage Area A3 to Store 4,000 t of Scheduled Coils	15
1.6.4	Experimentation Overview	17
1.7	Conclusions	17
1.8	Questions	18
2	Manufacturing System Planning and Scheduling	19
	<i>G. Merkur'yeva and N. Shires</i>	
2.1	Introduction	19
2.2	Problem Formulation	20
2.3	Modelling Approach	21
2.3.1	A High-Level Business/Manufacturing System Model	21
2.3.2	A Low-Level Anodising Process Stage Sub-Model	24
2.4	Experimentation	28
2.4.1	Planning Scenarios for Business Process Optimisation	28

2.4.2	Testing Sequencing Rules for Processing Production Orders	30
2.5	Conclusions	32
2.6	Questions	32
3	Supply Chain Dynamics	35
	<i>J.-C. Hennet</i>	
3.1	Introduction	35
3.2	A Model of a Supply Chain System	37
3.2.1	Presentation of the Dynamic Model	37
3.2.2	Some Properties of the Model	38
3.2.3	A Five-Product Example	39
3.3	The Production and Ordering Policies	40
3.3.1	The Inventory-Based Policy	40
3.3.2	The Order-Based Policy	41
3.3.3	The Mean-Demand-Driven Policy	41
3.4	Numerical Results	42
3.4.1	The Inventory-Based Policy	42
3.4.2	The Order-Based Policy	44
3.4.3	The Mean-Demand-Driven Policy	45
3.4.4	Variance Analysis for the Three Policies	46
3.5	Supply Chain Dynamics in Practice	46
3.5.1	The Beer Game	46
3.5.2	Some Real Consequences of the Bullwhip Effect	47
3.6	Conclusion	47
3.7	Questions and Assignments	48
4	Pharmaceutical Distribution Network	49
	<i>H. Van Landeghem</i>	
4.1	The Pharmaceutical Distribution Network	49
4.2	Determining Transportation Modes and Associated Unit Costs	52
4.2.1	Inbound Transportation	53
4.2.2	Outbound Transportation	53
4.3	Lane Mode Optimisation Model Using MILP	56
4.3.1	MILP Model Formulation	57
4.3.2	Experimental Design and Results	59
4.4	Conclusions	63
4.5	Assignments	63
5	Hospital Resource Management	65
	<i>R. M. Aguilar Chinea, I. Castilla Rodríguez and R. C. Muñoz González</i>	
5.1	Introduction: Objectives	65
5.2	Conceptual Model	66
5.2.1	Patient Flow Model	68
5.3	Verification and Validation	70

5.4	Experimentation	71
5.4.1	Implementation of a Gynaecological Consultation: Sequential Flow	73
5.4.2	Implementation of Gynaecological Visits and Diagnostic Tests: Combined Sequential–Simultaneous Flow	80
5.5	Conclusions	83
5.6	Questions	83
6	Supply Chain Cyclic Planning and Optimisation	85
	<i>G. Merkuryeva and L. Napalkova</i>	
6.1	Introduction	85
6.2	Problem Definition	86
6.2.1	Assumptions	87
6.2.2	Objective Functions	87
6.2.3	Decision Variables	88
6.2.4	Constraints	88
6.2.5	Express Analysis	88
6.3	Simulation Model Description	89
6.4	Optimisation Methodology	91
6.4.1	Simulation-Based Optimisation Scheme	91
6.4.2	Optimisation Methods and Software Add-On	92
6.4.3	A Two-Phase Hybrid Optimisation Algorithm	94
6.5	Experimentation	98
6.5.1	Optimisation Scenario 1	99
6.5.2	Optimisation Scenario 2	100
6.5.3	Optimisation Scenario 3	101
6.5.4	Optimisation Scenario 4	103
6.6	Conclusions	105
6.7	Questions and Assignments	106
	Appendix	106
7	Flexible Manufacturing Systems	109
	<i>M. Ángel Piera Eroles, M. Narciso Farias and R. Buil Giné</i>	
7.1	Introduction	109
7.2	Simulation Shortcomings to Improving FMS Performance	111
7.3	Managing Simulation Model Complexity	112
7.3.1	Petri Net Modelling Formalism	113
7.3.2	Reasons for Using Petri Nets	114
7.4	Coloured Petri Net Formalism	115
7.4.1	The Coverability Tree	116
7.5	System Description: a Flexible Manufacturing System	117
7.6	CPN Model	121
7.7	Results	124
7.8	Conclusions	124
7.9	Questions	125

8	Fresh-Food Supply Chain	127
	<i>A. Bruzzone, M. Massei and E. Bocca</i>	
8.1	Introduction	128
	8.1.1 Fresh-Goods Processing	128
	8.1.2 Logistics Solutions	129
8.2	Meat Distribution Simulator	131
	8.2.1 Redistribution Algorithms	134
8.3	Fresh Fish: Definition of Delivery Processes	135
	8.3.1 MARLIN Simulator	139
8.4	Conclusions	144
8.5	Questions	144
9	Warehouse Order Picking Process	147
	<i>Y. Merkurjev, A. Burinskiene and G. Merkurjeva</i>	
9.1	Introduction	147
9.2	Objectives of the Project	148
9.3	Description of Order Picking Process	148
	9.3.1 Warehouse Layout	149
	9.3.2 Storage Strategies	150
	9.3.3 Customer Orders	152
	9.3.4 Routing Methods in a Wide-Aisle Warehouse	152
9.4	Model Description and Instructions	153
	9.4.1 Warehouse Layout and Location Names Database	154
	9.4.2 Location Visit Identification Numbers Database	154
	9.4.3 Pick Lists Database	157
	9.4.4 Simulation Algorithm	159
9.5	Verification and Validation	160
9.6	Tasks for the Reader	161
9.7	Experiments	161
9.8	Concluding Remarks	164
9.9	Questions	164
10	Material Handling System	167
	<i>G. Neumann</i>	
10.1	Objectives of the Project	167
10.2	Description of the Material Handling System	168
	10.2.1 System Functionality	168
	10.2.2 System Structure and Boundaries	168
	10.2.3 Pallet Flows	170
	10.2.4 Process Control	170
10.3	System Analysis	172
10.4	Model Building	174
	10.4.1 The DOSIMIS-3 Simulation Package	174
	10.4.2 Model Structure	174
	10.4.3 Model Parameters	175
10.5	Verification and Validation	176