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To our daughter Lena and parents
Yuri Merkuryev and Galina Merkuryeva

To my wife Gemma, children Alba, Judit and Marc, parents Josep Mª and Mª 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 Merkuryeva 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 submodel 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 Merkuryev, Merkuryeva 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, Altiok, 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 interrelated constraints and variables: time-to-market, traceability, transport/storage conditions, handling, production/process control, demand variability and seasonal behaviours.

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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.

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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