# Preface

When looking back, we can say that the journey leading to this book started in the fall of 1994. At that time, the first author started to study the spare parts management at the Royal Netherlands Navy (RNN), which was part of a large maintenance project of the RNN and the University of Twente. Professor Henk Zijm suggested to use the METRIC type models of Craig Sherbrooke as described in his book of 1992. Shortly later, a Navy Officer, Jan Willem Rustenburg, started his PhD project on this topic, with Henk Zijm and the first author as supervisors. In this project, the METRIC type models were applied to cases at the RNN, an exact evaluation method for a general multi-echelon, multi-indenture system was developed, and problems with yearly budget constraints were studied. The cases showed the strength of the so-called system approach in comparison to a straightforward item approach.

In 1999, the first author moved to Eindhoven University of Technology, and he started to collaborate with multiple Original Equipment Manufacturers (OEMs) that manage large spare parts networks to serve their customers. Over the years, many master and PhD projects were carried out with companies such as ASML, DAF, IBM, KLM, Marel, NedTrain, Océ, Philips Healthcare, and Vanderlande Industries. In the spare parts networks of most of these companies, it is not common to backorder demands when stockouts occur, as assumed in the METRIC type models. Instead, lateral transshipments and emergency shipments are applied in order to satisfy a demand as quickly as possible. This avoids long and costly downtimes of the manufacturing and transportation equipment that is supported by the spare parts networks. Further, it was important to deal with multiple customer classes, each with their own target system availability level. This motivated the start of the final project of the second author in 2002 for the postgraduate program Mathematics for Industry. In this project, we collaborated with ASML, an OEM of expensive lithography equipment for the semiconductor industry. Subsequently, this project was continued with a PhD project.

In his PhD project, the second author developed new multi-item spare parts models and followed a system approach for all of them. Aspects that were included were commonality, service differentiation, lateral transshipments, and emergency

shipments. The people at ASML, Harrie de Haas, Eric Messelaar, and Harold Bol, were directly involved in the modeling phase. The potential of these new models for the practice of ASML was determined via case studies. One of these case studies showed a huge potential. That was for the multi-item, multi-location model with lateral transshipments. ASML used already lateral transshipments at the operational level, but this was not included in the spare parts planning model at the tactical planning level. The case study showed that including lateral transshipments at the tactical planning level gave an improvement potential of 30 %; see Chap. 5 for more details. This had an enormous impact. ASML implemented the lateral transshipments model in 2005, and they use the model for their tactical planning since early 2006, i.e., for already more than 9 years.

The PhD dissertation of the second author achieved both a high scientific level and a high practical relevance. It received a great appreciation from both the academic and business world. On top of that, the second author received the EURO Doctoral Dissertation Award 2007 of the Association of European Operational Research Societies for the best PhD dissertation defended at a European university within the Operations Research area. At that time, the idea arose to write the underlying book.

This book focuses on the tactical planning level for spare parts management. It describes a series of multi-item inventory models and presents exact and heuristic optimization methods, including greedy heuristics that work well for real-life size problems. The intended audience consists of graduate students, starting scholars in the field of spare parts inventory control, and spare parts planning specialists in the industry.

After an introductory chapter, we present a basic, single-location model in Chap. 2. This chapter forms a basis for all other chapters. Next, Chaps. 3 and 4 are on single-location models with multiple machine types and/or machine groups. In these chapters, we deal with commonality and service differentiation, respectively. In Chap. 5, we present the multi-location model with lateral transshipments. This chapter contains the successful case as mentioned above. In Chaps. 6 and 7, we deal with the classical METRIC model and its generalization to multi-indenture systems, respectively. Finally, in Chap. 8, we go back to a single-location model, and we have an explicit modeling of the repair capacity for failed parts and the priorities that one can set there. Chapters 3–5 are based on joint papers of the authors. Chapter 2 is based on lecture notes, written together with Kristel Hoen. Chapters 6–8 are based on papers with multiple other authors: Hartanto Wong, Dirk Cattrysse, Jan Willem Rustenburg, Henk Zijm, Ivo Adan, and Andrei Sleptchenko.

Various chapters of the book have been used in a master's course at Eindhoven University of Technology and in a PhD course of the Dutch Network on the Mathematics of Operations Research. The required pre-knowledge consists of probability theory and basic knowledge on Markov processes and queueing theory. We mainly used Chaps. 1, 2, 5, and 6 in these courses. Generally, we advise to start with Chaps. 1 and 2, and after that, one can do each of the Chaps. 3–6 and 8. Chapter 7 builds on Chap. 6, and thus Chap. 7 can only be treated after Chap. 6 has been studied.

We would like to thank many people, without whom this book would not have been there. First, we thank all co-authors as mentioned above. Next, we want to thank a number of colleagues at Eindhoven University of Technology. We are very grateful to Engin Topan, who executed the computational experiment in Sects. 3.4.1 and 3.4.2, gave a lot of feedback on all chapters, and helped us with the index at the end of the book. We also thank Joachim Arts, Erwin van Wingerden, and Martijn van Aspert for their feedback. We are grateful to Eindhoven University of Technology for its support during the whole process. Further, we want to thank all involved people at ASML for their collaboration, since we started to work with them. We also thank all involved people at Springer for their great support, regarding all kinds of things that have to be arranged when writing a book. In particular, we like to thank Fred Hillier, who as an editor kept us asking about the progress at a regular basis and who had always stimulating words when we reported that the progress was less than planned. Finally, we thank the many colleagues, friends, and family members who showed their interest in our book and denoted that they would like to see or even read the book when finished. Well, go ahead, our book is available now!

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