

Preface

This book presents some of the most important methods and tools available for modeling and solving problems arising in the context of supply chain management; in the context of this book, “solving problems” usually means “designing efficient algorithms for obtaining high-quality solutions”. Modeling a real-world problem so that it becomes amenable to analysis and the later design of algorithms for actually solving it is a fascinating mixture of art, science, and engineering. The major purpose of this book is therefore to show what modeling techniques can be expected to work for a given situation, as well as what kinds of constraints or objective functions can render models intractable, and what to do when omitting them is not an option; above all, how to apply existing proven exact or heuristic methods, or even design a hybrid or completely new algorithm for a particular model.

As is often the case with textbooks, the material in this book grew out of a set of lectures that I gave to M.Sc. students of Carnegie-Mellon University’s Master’s in Information Networking program, and Ph.D. level graduate students at Aalborg University, Aalborg, Denmark on the topics of Business Management for Engineers, Supply Chain Management and Logistics, and Network Optimization. The enthusiasm of my students encouraged me to carefully write my lecture notes in book form, and the end result is this book.

The content of the book is organized as follows: the first chapter is a review chapter on methods for continuous as well as combinatorial optimization. It covers most areas of modern optimization:

- Unconstrained non-linear optimization, where the main focus is on methods that converge to a local optimum or at least a saddle point, including Newton-like methods, conjugate-gradient methods, and trust-region methods, but there is also a discussion on successful meta-heuristics for global optimization: simulated annealing, evolutionary algorithms, genetic algorithms, the differential evolution method. Theoretical results are given to show any guarantee that a method has for convergence to a local optimum or a saddle point.

- Constrained linear optimization: the revised simplex method for linear programming is covered in some detail, as is the revised network simplex method for linear network optimization. Advanced topics in network optimization including auction algorithms for the linear assignment problem are also discussed.
- Constrained non-linear optimization: the first-order necessary conditions for mathematical programming are given using the standard theorems of the alternative, and first-order sufficient conditions are presented for convex functions. From an algorithmic point of view, penalty methods and Lagrangean multiplier methods are discussed.
- Combinatorial and mixed-integer optimization, where the focus is on the framework of the Branch-and-Bound method and its variants including Branch-and-Price, Branch-and-Cut-and-Price etc. Successful meta-heuristics including Tabu search and the more recent nested partitions method are also covered.

The chapter also includes an introduction to dynamic programming, which plays an important role on many problems in planning, scheduling, and inventory control. All the material in this chapter can be considered *classical*, with the exception of the recent introduction of the nested partitions method in the arsenal of people working on NP-hard combinatorial optimization problems. As such, it can be skipped by readers familiar with the general (finite-dimensional) optimization techniques and serve only as a reference when the need arises.

The second chapter is an introduction to (short and medium term) demand forecasting using mostly time-series analysis methods. Demand forecasting is a tactical problem that is however of great importance to supply chain management as it forms the basis for setting sales targets, production plans, and consequently and even more seriously, lead-times, personnel levels and so on. Besides the classical exponential smoothing methods and their many variants, and time-series regression methods, and decomposition methods, there is a detailed derivation of fast order-recursive methods (i.e. the Levinson-Durbin method) for solving the Yule-Walker equations arising in auto-regressive based forecasting which is not the standard material in such manuscripts. This is also the case for prediction markets and their information aggregation capabilities, presented in that chapter as well. The material on ensemble forecasts on the other hand, is based mostly on the author's own research, and some computational results and conclusions are presented for the first time.

The third chapter is an introduction to tactical and operational level planning and scheduling problems, seen from the point of view of the interface between Operations Research and Computer Science. In this case, the focus is on formulating accurate models that are at the same time amenable to efficient algorithms for solving them to optimality or at least to near-optimality. Hierarchical production planning is introduced as a vehicle for reducing problem complexity, which then allows one to formulate optimization models at each level of the hierarchy that can be solved exactly or for which fast and efficient heuristics exist, even for large-scale problems. The algorithms for crew assignment scheduling

problems provided here were developed in the context of my research on advanced decision support systems at Lucent Bell Labs, Transquest, and Delta Technology. Finally, the modeling of problems related to available-to-promise and order admission control and corresponding solution techniques are comprehensively presented here for the first time.

The fourth chapter deals with inventory control, a purely operational problem. The focus is mostly on single-echelon systems, but a brief discussion of the multi-echelon (serial) case is also presented. Starting with the simple case of deterministic and constant demand and the EOQ model, the text quickly turns to the much more challenging stochastic demand case. The material in this section requires a good understanding of probability theory and statistics. The modeling and analysis of such systems was completed more than forty years ago, but algorithms—exact or heuristic—for determining optimal policy parameters of some such systems have not appeared until very recently. For example, at the time of this writing, I have not been able to find any exact or heuristic algorithm for the (s, S, T) policy optimization under stationary demand and linear holding and backorder costs in the literature. In this chapter, both exact and fast heuristic algorithms for all major inventory control policies are discussed in detail, and computational results are provided.

The fifth chapter deals with the most strategic-level decision problems to be made in supply chain management, which are however intimately linked to operational-level decision problems: location theory and distribution management problems. A number of related location problems including the p -median problem, the uncapacitated and the capacitated facility location problem, as well as multi-echelon multi-commodity location/allocation problems are presented, modeled, and analyzed in this chapter, and efficient exact and heuristic methods are given for their solution. Some methods are again presented here for the first time (the cluster ensemble-based methods for the p -median and uncapacitated facility location problem in particular). Regarding distribution management, some of the most important techniques for vehicle routing problems under the general case of resource constraints and time windows are discussed. Both exact algorithms relying on column generation as well as carefully crafted heuristics are presented for this type of problem.

The last chapter (epilogue) presents a list of some problem areas that I deem will be of great importance in supply chain management in the near future. Some of these problems should be tackled via rigorous methods whereas other problems are purely information technology problems that should be attacked via rigorous software development techniques for building secure and dependable computing systems.

The intended audience of this book is advanced undergraduate and graduate students and researchers working on the interfaces of operations research and computer science; such persons are often affiliated with operations research, electrical and computer engineering, computer science, and industrial and systems engineering departments or graduate business schools. The prerequisites for understanding the material in this book are fairly standard: a two-semester

undergraduate-level course on calculus and linear algebra should be enough to follow the mathematical developments in the manuscript. A first course on programming and data structures is also necessary to be able to implement most of the algorithms in this book. The material in Chap. 4 also requires a good background (i.e. a one-semester undergraduate-level course) of probability; some results however are developed using the notions of stochastic convexity and its applications. Assuming the students have also had some exposure to optimization methods, the material in Chaps. 2–5 can be presented in one full semester course. Otherwise, appropriate sections from the optimization review first chapter must be presented in a two- or three-week time span, and then selected topics from Chaps. 2–5 can be presented in the remaining time, probably skipping the material on auto-regressive methods from Chap. 2, and the material on inventory control under stochastic demand in Chap. 4.

At this point, I would like to thank all my students who carefully read hard-to-read portions of unfinished manuscripts of this book and made very useful suggestions. I would like to especially thank my colleague, Dr. Sofoklis Efremidis for proof-reading the first drafts of chapter one of this book and suggesting many corrections and improvements, my student Mr. Yongming Luo for carefully reading the second chapter of the book and preparing some of the figures in it, and finally, Mr. Panagiotis Apostolopoulos for reading parts of the third chapter and making useful suggestions. And of course, I would like to thank the editorial team at Springer for excellent job editing, formatting, and typesetting the book.

Last but not the least, I would like to dedicate this book to my daughter, Anna, and to guarantee to her that I will make up for all the time that she did not get to play with me while I was preparing this book.

Athens, February 2011



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