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Inventory Analytics

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Abstract

“Inventory Analytics” provides a comprehensive and accessible introduction to the theory and practice of inventory control. The book outlines the foundations of inventory systems and surveys prescriptive analytics models for deterministic inventory control. It further discusses predictive analytics techniques for demand forecasting in inventory control and also examines prescriptive analytics models for stochastic inventory control.

Inventory Analytics is the first book of its kind to adopt a Python-driven approach to illustrating theories and concepts via computational examples, with each model covered in the book accompanied by its Python code. A GitHub repository containing all Python code discussed complements the book. Originating as a collection of self-contained lectures, the book will be an indispensable resource for practitioners, researchers, teachers, and students alike.

The aim of this extended abstract is to showcase the content of this book.

1 Introduction

Inventory control¹ is a thriving research area that plays a pivotal role, as a building block, in supply chain planning. For this reason, it attracts the attention of both industry and academia.

Selected topics from inventory control are regularly covered in academic programmes, at both undergraduate and graduate levels, offered by business schools, industrial engineering, and applied mathematics departments.

Problems faced by managers who engage with the challenges posed by inventory systems are generally simple to state, but complex to address. Obtaining good solutions to these problems requires a blend of expertise drawn from a variety of quantitative disciplines, such as operations research, economics, mathematics, and statistics.

¹These sections are excerpts from “Inventory Analytics” (<https://doi.org/10.11647/OBP.0252>) by R. Rossi, which is released under a Creative Commons Attribution 4.0 International (CC BY 4.0) license (<https://creativecommons.org/licenses/by/4.0>).

The majority of existing books in inventory control theory adopt, in my view, an overly mathematical and abstract style of presentation. This style appeals to researchers in the area, but makes these books often inaccessible to practitioners, as well as to some business school researchers who have not received advanced mathematical training such as that offered by applied mathematics, computer science, or industrial engineering curricula. A book with a more applied, hands-on focus is missing.

“Inventory Analytics” [1] aims to fill this void. It is aimed at those who want to learn the basics of modelling aspects of inventory control problems without needing to resort to the technical literature; at those who, despite lacking advanced mathematical training, want to access seminal findings in this field, and to apply well-established models by employing state-of-the-art solvers and modelling languages.

The book requires a working knowledge of Python; it is therefore aimed at readers who have, at the very least, taken a basic Python programming course. Apart from this, the book aims at stripping mathematical results to the bare minimum while preserving sufficient rigour, and at focusing on the practical relevance of these results in the context of the implementation of solution methods for problems typically faced by a manager who juggles with day-to-day inventory control challenges.

The book is structured as follows. It first provides a general introduction to inventory systems, followed by an overview of basic deterministic models. All these models are paired with their respective Python implementation, which can be tested on motivating examples that are presented throughout. The book is complemented by a GitHub repository that contains all Python code discussed [2]. After showcasing established models in deterministic inventory control, the reader is introduced to forecasting. Forecasting is often only briefly surveyed in existing books on inventory control; with the readers often directed to specialised textbooks, which are again often inaccessible to practitioners or individuals without suitable advanced mathematical training. However, forecasting is a crucial aspect of any practical inventory challenge. This work covers the most well-known forecasting models in a hands-on and visually appealing manner. The introduction of forecast errors paves the way to stochastic inventory control models, which are presented in the following sections. Once more, the most well-known stochastic inventory control policies are discussed in a hands-on fashion, with supporting code snippets and motivating examples. The last chapter briefly presents seminal results in the context of the control of multi-echelon inventory systems. Finally, an appendix provides the relevant formal backgrounds on a number of topics that are leveraged throughout the main chapters.

2 Inventory Analytics

This book originates as a collection of self-contained lectures. These lectures are divided into an introduction to inventory control, which outlines the foundations of inventory systems; followed by three chapters on deterministic inventory control, demand forecasting, and stochastic inventory control.

Beside Inventory, the title of the book refers to Analytics. This is nowadays a concept that has been inflated with a plethora of meanings, so that it becomes difficult to understand exactly what each of us means when we refer to it. The Cambridge Dictionary defines Analytics as “a process in which a computer examines information using mathematical methods in order to find useful patterns.” However, this appears to be quite a restrictive definition for our purposes.

To better understand the nature of Analytics, it is useful to observe that Analytics is often broken down into three parts: descriptive, predictive, and prescriptive. Descriptive Analytics is concerned with answering the question: “what happened?” Predictive Analytics is concerned with answering the question: “what will happen?” Prescriptive Analytics is concerned with answering the question: “how can we make it happen?” These are clearly complex questions that cannot be answered by mere *number crunching* on a computer: to answer these questions a decision maker must leverage soft as well as hard skills.

Many tend to think that the Analytics phenomenon is a recent development related to widespread availability of computing power. However, in his work “De Inventione,” the Roman philosopher Cicero states that “there are three parts to Prudence: Memory, Intelligence, and Foresight.” It is clear that Memory is the skill required to answer the question “what happened?”; Foresight, that required to answer the question “what will happen?”; and Intelligence, that required to answer the question “how can we make it happen?” It appears then that Analytics is just a contemporary rebranding of an art that has been known for millenia. *Prudentia* is the ability to govern and discipline oneself by the use of reason. *Inventio* is the central canon of rhetoric, a method devoted to systematic search for arguments. Incidentally, *inventio* also means inventory. In fact, when a new argument is found, it is *invented*, in the sense of “added to the inventory” of arguments. *Prudentia* and *Inventio* are the foundations upon which the art of Rhetoric stands.

It must not surprise us then that Analytics plays a prominent role in inventory management. Inventory management finds its roots into the practice of late medieval and early Renaissance merchants. The invention of double-entry bookkeeping (alla Veneziana) is typically attributed to Frà Luca Pacioli (c. 1447 – 19 June 1517). Pacioli leveraged Johannes Gutenberg’s new technology to disseminate and popularise accounting practices that had been in use among Venetian merchants for a long time. However, Pacioli did not simply disseminate existing practices, he reinterpreted these practices within the framework of Cicero’s rethoric. In “De Inventione,” Cicero ex-

plains that there are five canons, or tenets, of Rhetoric: *Inventio* (invention), *Dispositio* (arrangement), *Elocutio* (style), *Memoria* (memory), and *Pronuntiatio* (delivery). Pacioli’s “Tractatus de computis et scripturis” (1494), is divided into two main sections: (i) the Inventory, and (ii) the Disposition — the influence of Cicero’s work is apparent. Pacioli writes: “In order to conduct a business properly a person must: possess sufficient capital or credit, be a good accountant and bookkeeper, and possess a proper bookkeeping system.” In “the Inventory,” Pacioli writes “The merchant must prepare a list of his inventory. Items that are most valuable and easier to lose should be listed first. [...] The inventory should be carried out and completed in a single day. [...] The inventory is to include the day that the inventory was taken, the place, and the name of the owner.” In contemporary terms, Pacioli describes a so-called “physical inventory,” the process by which a business physically reviews its entire inventory — as opposed to so-called “cycle counts,” which focus on specific subsets of items. In “the Disposition,” Pacioli describes the necessary books and rules to implement double-entry bookkeeping.

Pacioli’s work represents a quantum leap in the realm of *descriptive inventory analytics*, a discipline that would evolve into a fundamental part of inventory management. However, no progress was made in the realm of *predictive* and *prescriptive inventory analytics* until late 1800, when Edgeworth, in his “Mathematical Theory of Banking,” used the central limit theorem to determine cash reserves needed to satisfy random withdrawals from depositors, thus embedding a *predictive* probabilistic model within a *prescriptive* mathematical model to support inventory control decisions.

From these early results, over the past 150 years, inventory control has evolved into an independent discipline. The aim of this book is to provide an introduction to this discipline.

After introducing the foundations of inventory systems, in chapter “Deterministic Inventory Control” we survey *prescriptive analytics* models for deterministic inventory control, in chapter “Demand Forecasting” we discuss *predictive analytics* techniques for demand forecasting in inventory control, which originate in the realm of time series analysis and forecasting. Finally, in chapters “Stochastic Inventory Control” and “Multi-echelon Inventory Systems” we survey *prescriptive analytics* models for stochastic inventory control.

References

- [1] Roberto Rossi, Inventory Analytics, 184 pages. Open Book Publishers, Cambridge, UK (2021)
- [2] Roberto Rossi, inventoryanalytics: a Python library dedicated to Inventory Analytics, <https://github.com/gwr3n/inventoryanalytics> (2022)