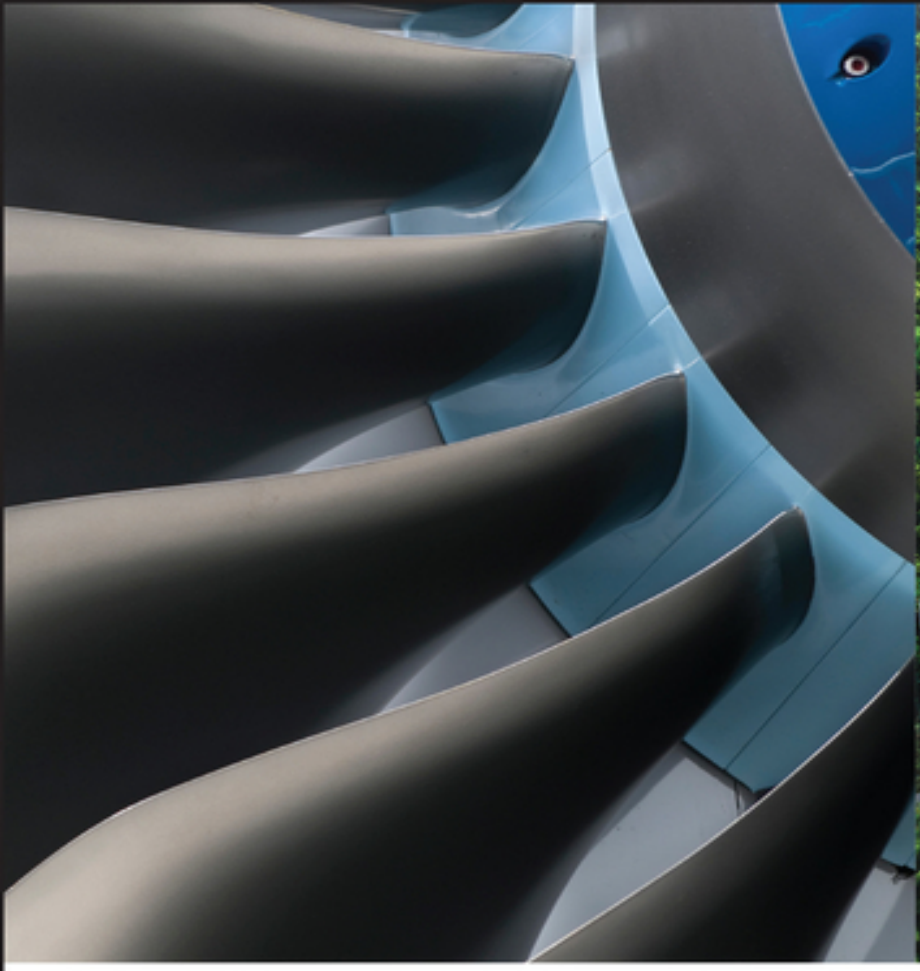

INTERMITTENT DEMAND FORECASTING

CONTEXT, METHODS AND APPLICATIONS

JOHN E. BOYLAN
ARIS A. SYNTETOS

with website

WILEY

Table of Contents

List of Tables

Chapter 3

List of Illustrations

Intermittent Demand Forecasting

Context, Methods and Applications

John E. Boylan
Lancaster University
Lancaster, UK

Aris A. Syntetos
Cardiff University
Cardiff, UK

WILEY

This edition first published 2021

Registered Offices

John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA

John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Office

9600 Garsington Road, Oxford, OX4 2DQ, UK

For details of our global editorial offices, customer services, and more information about Wiley products visit us at www.wiley.com.

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

Library of Congress Cataloging-in-Publication Data applied for

ISBN 978-1-119-97608-0 (hardback); LCCN - 2021011006

Cover Design: Wiley

Cover Image: Mata Atlantica - Atlantic Forest in Brazil © FG Trade/Getty Images, Turbine © Brasil2/Getty Images

For Jan and Rachel

Preface

The images on the front of this book highlight a crucial tension for all advanced economies. There is a desire to travel more and consume more, but also a growing awareness of the detrimental effects that this is having on the environment. There is a belated realisation that those of us living in countries with developed economies need to consume less and waste less.

Waste can occur at all stages of the supply chain. Consumers may buy food they never eat or clothes they never wear. Retailers and wholesalers may order goods from manufacturers that never sell. These wastages can be significantly reduced by better demand forecasting and inventory management. Some items conform to regular demand patterns and are relatively easy to forecast. Other items, with irregular and intermittent demand patterns, are much harder.

Wastage can be addressed by changes in production, moving away from built-in obsolescence and towards products that can be maintained and repaired economically. For this to be an attractive proposition, spare parts need to be readily available. Unfortunately, these items are often the most difficult to forecast because many of them are subject to the sporadic nature of intermittent demand. Although there have been significant advances in intermittent demand forecasting over recent decades, these are not all available in commercial software. In the final chapter of this book, we highlight the progress that has been made, including methods that are freely available in open source software.

The reasons for the slow adoption of new forecasting methods and approaches in commercial software are varied. We believe that one of the reasons is a lack of appreciation of the benefits that may accrue. Because intermittent demand items are so difficult to forecast, it may be thought that *highly accurate* forecasting methods can never be found. This may be true. However, it is possible to find *more accurate* methods, which can contribute towards significant improvements in inventory management.

There is also a need for greater awareness of the methods that have been developed in recent years. Information on them is scattered amongst a variety of academic journals, and some of the articles are highly technical. Therefore, we have set ourselves the challenge of synthesizing this body of knowledge. We have endeavoured to bring together the main strands of research into a coherent whole, and assuming no prior knowledge of the subject.

There are various perspectives from which demand forecasting can be addressed. One option would be to take an operations management view, with a focus on forecasting and planning processes. Another would be to take a more statistical perspective, starting with mathematical models and working through their properties. While some of our material has been influenced by these orientations, the dominant perspective of this book is that of operational research (OR). The start point of OR should always be the real-life situation that is encountered. This means that it is essential to gain an in-depth understanding of inventory systems and how forecasts inform these decisions. Such an appreciation enables a sharper focus on forecasting requirements and the appropriate criteria for a ‘good forecast’.

In this book, the first three chapters focus on the inventory management context in which forecasting occurs, including the inventory policies and the service level measures that are appropriate for intermittent demand. Recognising the interconnection between inventory policies, demand distributions, and forecasting methods, the next two chapters focus on demand distributions, including evidence from studies of real-world data. The following two chapters concentrate on forecasting methods, with discussion of practical issues that must be addressed in their implementation. We then turn to the linkage between forecasts and inventory availability, and review how forecast accuracy should be measured and how its implications for inventories should be assessed. We also look at how stock keeping units should be classified for forecasting purposes, and examine methods designed specifically to address maintenance and obsolescence. The next two chapters deal with methods that can tackle more challenging demand patterns. We conclude with a review of forecasting software requirements and our views on the way forward.

We are grateful to those pioneers who inspired us to study this subject, and who have given us valuable advice over the years, especially John Croston, Roy Johnston, and Tom Willemain. We would like to express our thanks to those who commented on draft chapters of this book: Zied Babai, Stephen Disney, Robert Fildes, Thanos Goltsos, Matteo Kalchschmidt, Stephan Kolassa, Nikos Kourentzes, Mona Mohammadipour, Erica Pastore, Fotios Petropoulos, Dennis Prak, Anna-Lena Sachs, and Ivan Svetunkov; and to Nicole Ayiomamitou and Antonis Siakallis who helped with the figures.

Lancaster and Cardiff
January 2021

John E. Boylan
Aris A. Syntetos

Glossary

ADIDA
: aggregate–disaggregate intermittent demand approach

AIC
: Akaike information criterion

AR
: autoregressive

ARIMA
: autoregressive integrated moving average

ARMA
: autoregressive moving average

APE
: absolute percentage error

BO
: backorder

BoM
: bill of materials

BS
: Brier score

CDF
: cumulative distribution function

CFE
: cumulative forecast error

CSL
: cycle service level (all replenishment cycles)

CSL^{+}
: cycle service level (replenishment cycles with some demand)

CV

coefficient of variation

EDF
empirical distribution function

ERP
enterprise resource planning

FMECA
failure mode, effects, and criticality analysis

FR
fill rate

FSS
forecast support system

FVA
forecast value added

HES
hyperbolic exponential smoothing

INAR
integer autoregressive

INARMA
integer autoregressive moving average

INMA
integer moving average

IP
inventory position

KS
Kolmogorov–Smirnov (test)

LTD
lead-time demand

MA
moving average

MAD
mean absolute deviation

MAE
mean absolute error

MAPE
mean absolute percentage error

MAPEFF
mean absolute percentage error from forecast

MASE
mean absolute scaled error

ME
mean error

MMSE
minimum mean square error

MPE
mean percentage error

MPS
master production schedule

MRO
maintenance, repair, and operations

MRP
material requirements planning

MSE
mean square error

MSOE
multiple source of error

MTO
make to order

MTS
make to stock

NBD
negative binomial distribution

NN
neural network

NOB
: non-overlapping blocks

OB
: overlapping blocks

OUT
: order up to

PIS
: periods in stock

PIT
: probability integral transform

RMSE
: root mean square error

rPIT
: randomised probability integral transform

S&OP
: sales and operations planning

SBA
: Syntetos–Boylan Approximation (method)

SBC
: Syntetos–Boylan–Croston (classification)

SCM
: supply chain management

SES
: single (or simple) exponential smoothing

SKU
: stock keeping unit

SLA
: service level agreement

SMA
: simple moving average

sMAPE
: symmetric mean absolute percentage error

sMSE
: scaled mean square error

SOH
: stock on hand

SOO
: stock on order

SSOE
: single source of error

TSB
: Teunter–Syntetos–Babai (method)

VZ
: Viswanathan–Zhou (method)

WMH
: Wright Modified Holt (method)

WSS
: Willemain–Smart–Schwarz (method)

About the Companion Website

This book is accompanied by a companion website.

www.wiley.com/go/boylansyntetos/intermittentdemandforecasting

This website includes:

- Datasets (with accompanying information)
- Links to R packages