International Series in
Operations Research & Management Science

G.S.R. Murthy

Applications of Operations Research and Management Science

Case Studies

Springer

International Series in
Operations Research & Management Science

G.S.R. Murthy

Applications of Operations Research and Management Science

Case Studies

Springer

International Series in Operations Research & Management Science

Volume 229

G.S.R. Murthy

Applications of Operations Research and Management Science

Case Studies

Springer

G.S.R. Murthy
Indian Statistical Institute
Hyderabad, India

ISSN 0884-8289 ISSN 2214-7934 (electronic)
International Series in Operations Research & Management Science
ISBN 978-3-319-17920-9 ISBN 978-3-319-17921-6 (eBook)
DOI 10.1007/978-3-319-17921-6

Library of Congress Control Number: 2015939080

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

To my late parents

G. S. Acharyulu

and

Kanakavalli

Foreword

I, myself, am an alumnus of the Indian Statistical Institute (ISI). I studied in their M. Stat. program between 1955 and 1957 and learnt my early reasoning and mathematical skills during those years. I became acquainted with the "operations research (OR)", a new subject being developed around that time, in lectures at ISI by a visiting American faculty under a United Nations Visiting Faculty Program. I learnt about the "travelling salesman problem (TSP)" in one of those lectures and found it so challenging that I kept thinking about ways for solving it. The director of the SQC & OR Division of ISI at that time, Mr. S. C. Sen, saw my preoccupation with the TSP and encouraged me to apply for the Fulbright Travel Grant for a year's study at an American university, just being introduced at that time, so that I could learn OR for carrying out my research on the TSP with ISI providing funds for my living expenses if I succeeded in getting the Fulbright Travel Grant.

With Mr. S. C. Sen's help, I received the grant and spent the 1961–1962 academic year at the Case Institute of Technology in Cleveland, Ohio, learning OR and, while there, I developed the branch and bound method for the TSP. With that excellent beginning, I was off to a research career in OR. You can understand why I consider ISI a great educational institute and why I consider myself fortunate in being educated at ISI.

Around that time, I realized that there are really two branches for research in OR. One is "theory" (including the development of methods and algorithms) and the other is "practice" dealing with applying the methods to solve decision-making problems in real-life applications. Unfortunately, in those days each of the two groups "theoreticians" and "practitioners" had very low respect for the other group. This was the reason for the story: practitioners said that "theoreticians do nothing practical," while theoreticians said that "practitioners do practically nothing."

Philosophically I am opposed to fences, and even though I started doing research in theory, I considered myself belonging to both the groups. However, I also had the opinion that working in practice is easier than working in theory, perhaps created by

the fact that all the textbooks in OR at that time are theory books with only minor discussion of applications.

I had to drastically revise my opinion about practice being easier than theory when I started working on the decision-making problems in the storage of arriving containers at Hong Kong International Terminals, to reduce congestion on the terminal road network, which was traced as the main reason for delaying container trucks from reaching shore cranes, thus reducing the productivity of those cranes. I found the problem of developing an appropriate mathematical model for this problem to be very hard; initially, I could not even figure out what the appropriate decision variables in the model should be.

So, I looked up journal publications on the problem. Some of them modelled the problem using binary variables representing the allocation of available storage spaces in the storage yard to each of the arriving containers, which led to a large 0–1 model for the problem. Unfortunately, I found that this model is not only impractical but also totally inappropriate, as the set of available storage spaces in the storage yard changes uncontrollably due to constant reshuffling of stored containers in daily operations.

Then, I tried to model the problem as a multi-commodity flow problem to equalize the flow of container trucks on all the arcs of the terminal road network and, over time, as much as possible to minimize congestion. Sadly, this model was also found to be inappropriate for the problem, as truck drivers resented being told what routes to take and also as the flow rates of arriving containers is quite uneven over time because of the stochastic nature of vessel arrivals.

It took us several months of getting intimate knowledge of the various daily operations inside the terminal and hard thinking to come up with a suitable mathematical model for this problem based on a substitute objective function technique.

Given this background, you can see why I commend this effort by the author, Prof. G. S. R. Murthy, in preparing this textbook to teach modelling skills to students and practitioners of OR, based on over 10 interesting and challenging applications in a wide variety of application areas. In preparing this book for his students and clients, he is carrying on the tradition of ISI as an excellent educational institution.

My best wishes for the success of his book and to his students for very successful careers.

Hyderabad, India
February 2015

Katta Gopalakrishna Murty

Preface

The case studies presented in this book have evolved from my close association with a wide variety of industries over the past three decades. As a trainer and a consultant, I had the opportunity of working with industrial personnel at all levels and could gain a good insight into the ground realities and the state of management of operations in a large number of industries. In most of the industries, there is a huge scope for promoting applications for optimal decision making. Due to routine way of functioning, the executives and managers fail to recognize and identify opportunities for improvement studies. The main problem stems from the fact that they have little or no exposure to case study models which present the practical problems from a practitioner's perspective. There has been a frequent demand from them for books with specific case studies covering modelling aspects without getting much into mathematics. This has been one of the motivating factors for writing this book.

Many academic programmes on quality management, business management, and engineering disciplines at graduate and postgraduate levels emphasize the need for practical training as part of their course curricula. The Indian Statistical Institute runs a 6-month part-time academic programme exclusively for executives from industry with the objective of promoting applications of statistics and operations research in industry. Being a teacher in academic programmes and having close association with industry, I had the opportunity of training and guiding many of these students/participants on carrying out a number of application projects. Many of these students and participants have also been asking me to write a book on realistic case study applications. This is another motivating force to write this book. Some of the case studies presented in this book are taken from the studies in which the students/participants were involved.

Another source of inspiration for writing this book is my own fascination for the subject of applying statistics and operations research to industrial problems and helping the industrial personnel in promoting the applications.

Most of the problems in industry can be modelled with fundamental techniques of statistics and operations research. Sometimes very simple tools provide very powerful solutions. The chapter on the procedure of testing vaccines (Chap. 3) is a nice

example for this. Almost all applications of operations research I have come across use linear programming or integer linear programming formulations and nothing beyond. What makes these applications difficult is recognizing the problems, identifying the decision variables and constraints, and modelling the problems. Therefore, I sincerely believe that applications can be promoted even with limited knowledge of the fundamental tools and techniques and what is required is the skill of modelling the problem. Many authors of operations research think that modelling is an art. While this is true to some extent, many of the problems are typical in their nature, and hence, knowledge of case studies should be of great help in promoting the applications.

I have written this book keeping the above thoughts in mind and using the experience I have gained over the years from my interaction with students as a teacher and with industrial personnel as a trainer and consultant. Much of the emphasis is laid on understanding the problem, identifying the decision variables, understanding and formulating the constraints, and modelling the problems. As far as the operations research applications are concerned, mathematics is kept at a minimum level. The only exception perhaps is Chap. 10 which is about constructing an efficient design for an industrial experiment that was to be performed in a foundry. For the cases concerning statistical applications, some background knowledge is expected. These cases include applications of reliability, multivariate analysis, and Markov chains. For these studies, it is recommended that the readers should focus more on understanding the problems and identifying the right tools.

Fortunately, we are in the age of powerful computing resources. Once a problem is formulated, there are a number of software packages that can be used for solving the problem. In this direction, I find that in majority of the cases, industries still use Microsoft Excel for handling data, and any solution provided using excel is the first preference as it is user-friendly and cost saving.

I have selected ten case studies for this book, and each one of them is presented as a chapter. Again Chap. 7 is an exception to this. Chapter 7 covers five cases and it is about intelligent modelling. I believe that some of the chapters will be very useful for those who aspire to become consultants or provide software solutions by developing decision support systems. For example, using the detailed presentation on how deckle optimization can be done in paper and paperboard industries (Chap. 5), one can develop a software package for the deckle optimization problem. A brief overview of the chapters and their background is presented below.

Chapter 1 deals with a material optimization problem. The problem is about minimizing sheet metal consumption of mild steel used for producing automobile parts. It uses simple integer linear programming. This application was taken up as a project by one of the participants (of the part-time programme for industrial executives) as a part of his academic curriculum.

Chapter 2 is about minimizing production time of producing printed circuit boards. The problem is a complex combinatorial optimization problem. A nice heuristic is available for this problem which uses the travelling salesman problem and the assignment problem models. A software tool was developed for the manager to make quick and near optimal decisions for this problem.

Chapter 3 deals with a test procedure for quality control of hepatitis B vaccine. This study was carried out for a biotechnology company. A part of the test procedure involved conducting in vivo test on animals which was time consuming and considered unethical. Through a systematic analysis of the past data, a statistical test procedure which uses in vitro data was proposed as an alternative to the in vivo test. Appreciating the case study, the company was provided a great relief by the concerned drug authorities.

Chapter 4 is about the development of a decision support system for a large cement manufacturing company. The problem is about macro level planning of loading the plants of the company situated in different locations with various brands of cement and planning the despatches to the company's stockists based on their monthly orders. The chapter presents only the modelling aspects. The problem is a large-scale optimization problem which is a multi-commodity network flow problem. An important contribution of this study is that it presents a method of finding optimal solution under the unknown fluctuating prices scenario.

Chapter 5 is about deckle optimization in paper and paperboard industries. Paperboard industries invest huge money in procuring software for managing deckle optimization problem. The problem falls under the one-dimensional cutting stock problem and involves solving integer linear programming problems. Intelligent modelling is essential to solve the cutting stock problems arising in the context of deckle optimization. With a brief introduction to the products and processes relevant to this case study, the chapter presents various formulations to handle the challenges. Time and material costs are two conflicting components of the deckle optimization problem. The formulations proposed aid the user to explore the consequences of weighing these two conflicting factors while choosing the strategy for optimal decision making. This is yet another study where a student of a part-time academic programme took it up for his project work.

Chapter 6 was taken up for an information technology enabling services company. It is about planning and managing the agents/associates who receive the calls and address them. It turns out that this problem is too complex to handle manually. The problem is formulated as an integer linear programming problem, and a software tool is developed to aid the management. The tool is Excel based, is simple to use, and can be effectively deployed as a decision support system. This study was initiated by an executive from the company who took it up as his project work for his part-time academic programme.

Chapter 7 is about intelligent modelling of industrial problems. Industries often approach consultants with specific questions or problems. There is a great deal of demand for consultants in this regard. Some problems, though straightforward in terms of formulation, need special techniques for solving them. This chapter presents five live cases of industrial problems, some requiring special solutions and some requiring statistical modelling.

Chapter 8 presents a model for the management of water distribution and scheduling for given availabilities and requirement of water at various crop locations in irrigation ayacut. The chapter provides a model and framework for the problem in question. The problem is formulated as a dynamic minimum cost network flow

problem and provides an approach to solve the problem using static network flow models. A need-based software is also developed to solve the network flow problems. Some issues in the programming are discussed. A postgraduate student was involved in this study.

Chapter 9 deals with the development of an alternative method to measure the land/sea ratio, an important performance measure of tyres. The company's method depends on the skill of a technical person and uses a costly measuring equipment. It takes almost 3 days to get the measurements for each day's samples. The alternative method proposed through the study uses statistical techniques and a simple computer program. The result is instantaneous, removes the subjectivity, and disposes the need of a technical expert and the need of the costly measuring equipment. This study is the project work of a master of science (statistics) student.

Chapter 10 deals with development of an efficient design for conducting a factorial experiment required at an aluminium alloy foundry. Failing to get a satisfactory design for the experiment from the literature, a design was constructed using an ad hoc method. It is transparent from the method of construction that the design provides efficient estimates for all the required main effects and interactions. The method is extended to more general situations and is translated into a systematic approach. The method consists of formulating the construction problem as certain integer linear programming problems. The main purpose of including this study as a chapter in this book is to highlight the fact that research is an important faculty of a successful consultant.

Hyderabad, India G.S.R. Murthy
February 2015

Acknowledgements

There are a number of people who have contributed directly or indirectly in carrying out the case studies. These people include industrial personnel at various levels, my colleagues and seniors from the Indian Statistical Institute, the students of the academic programmes whom I taught and guided on their project works, a number of industrial executives who were the participants of the part-time programme run by the institute (a potential source for applications), and the organizational staff who helped in various ways. I thank each one of them for their kind cooperation.

Professor Katta Gopalakrishna Murty consolidated my passion for practical OR applications and provided constant support and encouragement. I am privileged to contribute five chapters along with other authors to his edited volume *Case Studies in Operations Research – Applications of Optimal Decision Making* recently published by Springer. Inspired by this, I expressed my desire to publish this volume with Springer. Upon his recommendation, I sent a draft proposal to Camille Price and I got a spontaneous reply from her recommending strongly to publish my case studies with Springer. I hereby record my deepest gratitude to both Professor Katta Murty and Camille Price. Further, the support I have received from Matthew Amboy and Christine Crigler is excellent. My sincere thanks to both of them. Working with the Springer team has been smooth and comfortable.

Much of the success I cherish today I owe it to two persons – my Guru Professor T. Parthasarathy and my wife Haripriya. They have been the spirit behind all my works. I record my deepest gratitude to Professor Parthasarathy. I don't need to thank Haripriya because she is my better half.

G.S.R. Murthy