Carlos F. Daganzo

Logistics Systems Analysis

Fourth Edition

Springer

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Fourth Edition
with 70 Figures
and 4 Tables

Springer

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Preface to the Fourth Edition

This expanded edition of "Logistics Systems Analysis" includes new research results and numerous modifications to enhance comprehensiveness and clarity. It has two new sections, a new appendix, and more than half a dozen new figures. A few references have also been added, but the bibliography is not exhaustive. Much of the new material is based on work by Profs. Alan Erera (Georgia Tech), Karen Smilowitz (Northwestern U.), and by PhD candidate Yanfeng Ouyang (U.C. Berkeley). Their help is gratefully acknowledged. The financial support of the National Science Foundation and the Volvo Foundations Center of Excellence for the Future of Urban Transportation at U.C. Berkeley is also acknowledged.

The new appendix presents the logic behind the traveling salesman and vehicle routing results used in Sec. 4.2 to describe the transportation operation; Chapter 4 is more self-contained as a result. New section 5.6 introduces and evaluates a general method that automatically translates the continuum approximation recipes of Chapters 4 and 5 into discrete system designs. This closes a gap in previous editions. Other additions include an explanation of how to develop system designs that can efficiently accommodate real-time control strategies to manage uncertainty (new section 4.6.3), and extensions of the many-to-many design ideas of Chap. 6 (in expanded section 6.5.3). An errata corrigendum will be posted on the authors's web site: http://www.ce.berkeley.edu/~daganzo/ This web site also explains how to order the solution manual to the problems in the book (professors only).

Carlos F. Daganzo
Berkeley, California
November 2004

Preface to the Third Edition

Aside from the removal of minor errors, the main modification in this printing of "Logistics Systems Analysis" is an improved explanation of many passages that had been found confusing by colleagues and students, most notably in chapters 5 and 6. A few references have also been added, mostly having to do with material complementary to that of the book.

I would like to acknowledge the comments of Profs. Eric Mohr, Wei Lin, and David Lovell, and the input of graduate students Flavio Baita, Alan Erera, Reinaldo Garcia, and Juan Carlos Muñoz.

Carlos F. Daganzo
Berkeley, California
November 1998

Preface to the Second Edition

The presentation and ideas in this second edition of "Logistics Systems Analysis" remain essentially unchanged from those of the first edition. The main modifications are the inclusion of an index, a more current reference list with brief discussions where appropriate, editorial changes to improve clarity, and the removal of a number of errors that had crept in the 1991 edition.

After teaching from this monograph for a number of years, I have found that students do not really master the material in it until they have used it to *formulate* and solve real life problems of interest to them. Although solving a number pre-formulated problems is no substitute for this experience, such an effort can be a useful first step toward the ultimate goal. In view of this, an informal set of solutions to some of the exercises listed at the end of each chapter has been developed. They can be ordered by writing to the Institute of Transportation Studies, Publications Office, 109 McLaughlin Hall, University of California, Berkeley, California, 94720.

My sincere gratitude goes to Mrs. Ping Hale for her skillfull preparation of the revised manuscript, and to the University of California Transportation Center for funding our efforts.

Carlos F. Daganzo
Berkeley, California
August, 1995

Preface to the First Edition

Logistics, the subject of this monograph, is narrowly defined here to be the science that studies how to convey items from production to consumption in cost-effective ways; some subjects of interest to logistics managers such as reliability and maintenance are not addressed. The theories that are covered, on the other hand, apply to generic items that can represent people, as well as freight; they should be of interest to passenger transportation firms and agencies.

Besides transportation, a logistics system usually includes other activities such as inventory control, handling, and sorting, which must be carefully coordinated if cost-effectiveness is to be achieved. Yet, both in theory and practice these activities are often examined separately.

The operations research field includes sub-fields with specialized journals in inventory control, transportation, warehousing, etc... Over the years, these sub-fields have evolved into disciplines that have developed their own specialized conventions and jargon, as a result making it increasingly difficult for researchers to communicate across disciplinary boundaries. Something similar happens in practice when firms become compartmentalized; if responsibilities for different logistical activities are allocated to different managers, decisions in the best interests of the firm are difficult (if not impossible) to make.

This monograph represents an attempt to examine logistics systems in an integrated way. By necessity, we will not represent any of the activities as precisely as would be done in each one of the sub-fields of *OR,* but we will try to model them accurately enough to capture their essence. Our goal is to describe, and show how to find, rational structures for logistics systems, including their operation and organization.

This monograph also departs from traditional operations research procedures in that it tries to avoid detailed descriptions of both problems and their solutions. For a typical problem, instead of searching for the ultimate solution based on reams of detailed data and time consuming numerical analyses, our goal will be to present reasonable solutions (described in terms of their properties) with as little information as possible. In fact a goal of our analyses will always be to determine what is the *least* amount of information that is needed to make a rational decision, and to use the simplest most transparent approach possible to identify good solutions. These features of our approach can help overcome the decision-makers' natural distrust of "black-boxes", and be quite helpful in instances where

time is of the essence. This is not to say that the more traditional detailed approaches to problem solving should not be used; when time and information availability allow it, numerical detailed methods have proven to be quite useful. Yet, even in these instances detailed solutions sometimes can be improved if they are preceded by an exploratory analysis as described in this monograph.

The work presented in this monograph is a result of efforts undertaken by this author, his close colleagues and students for the last decade.

In the early eighties, Dr. Larry Burns of the General Motors Research Laboratories and I became interested in the internal movement of goods of a large firm. Because transportation in a large firm shares many similarities with public transportation, we realized that, as had been done in the 70's for transit design problems and location problems by Prof. Newell (of the University of California, Berkeley) and his students, it was possible to substitute large numbers of data by suitable averages and to treat discrete problems in a continuous manner. We did not suspect at the time the impact that this endeavor was to have on General Motors. (To date, and using this approach, the General Motors research team headed by Dr. Burns has been commended repeatedly for numerous logistics improvements at *GM*).

In an effort to formalize this thinking, Newell and I taught an advanced 1 unit graduate seminar at U.C. Berkeley in 1982. Later that year I expanded and tested these notes while on sabbatical leave at M.I.T., hosted by Prof. Yosef Sheffi. Since then work has continued, with the contribution of Prof. Randolph Hall of U.C. Berkeley being particularly noteworthy, and the most current ideas are now taught in a four unit graduate course on networks and logistics.

Although most of the ideas in the course have been documented in the open literature, Professor Martin Beckmann (of Brown University) remarked at an *EURO/TIMS* conference in Paris in the late 80's that it is not easy for an "outsider" to get an overall view of this work. He convinced me that too many journals have published articles on the subject (sometimes with an unnatural chronology), and thus planted the seed for this monograph in my mind.

Mostly based on published works, this monograph attempts to present the subject in a logical way. New ideas are also presented when, in order to tell a cohesive story, "voids" in the literature had to be filled. Voids still remain and, hopefully, the monograph will spur further work on this young and evolving subject.

The first two chapters introduce preliminary ideas. Chapter 1 illustrates, by means of an example, the problem solving philosophy of the monograph, and Chapter 2 explains the accounting method for logistics costs. Chapters 3 through 6 describe the theory as is applied to gradually more

complex problems. Chapter 3 explains the optimization method in detail and illustrates it with a problem involving only one origin and one destination. Chapter 4 examines problems with one origin and many destinations (or vice versa), assuming that each item travels in only one vehicle; Chapter 5 allows for transshipments at intermediate terminals. Finally, Chapter 6 examines "many-to-many" problems.

Before getting started, some remarks about notation and organization need to be made. Equations, tables and figures will be numbered *(a.b),* where *"a"* is the chapter number and *"b"* the equation number. Also, because an attempt has been made to use as consistent a set of symbols throughout the monograph as possible, the reader should expect the notation often to be quite different from that in the references, which is unavoidable. Each chapter begins with some brief remarks on a few recommended readings that are closely related to the topic at hand, and ends with a set of suggested exercises and a list of symbols. A reference list with the bibliographic citations is provided at the end of the monograph.

Although not its main goal, the monograph could be used for teaching graduate students about logistics, perhaps in a course also covering the more traditional *OR* optimization tools. It should be possible to cover the most basic ideas in 10 one hour classes with about two classes per chapter, but a lengthier exposition is recommended to delve into details. To this effect, each chapter contains a few suggested exercises, intended to solidify the students' grasp of the concepts in the chapter and/or explore extensions that could not be discussed in the text.

In closing, I would like to thank my friends and colleagues, Profs. Gordon Newell and Randolph Hall of the University of California (Berkeley), and Dr. Lawrence Burns of General Motors Corporation, for their contribution to the ideas in this monograph.

I also thank Mrs. Phyllis DeFabio and Mrs. Ping Hale for their patience and perseverance in preparing the various versions of this manuscript. Ms. Gail Feazell prepared most of the Figures. The support of the Institute of Transportation Studies is also gratefully acknowledged. But most of all, I appreciate the love and understanding of the beauties and beauticians of my life.

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