Preface

Linear programming (LP) (Dantzig 1948, 1951a,b,c) might be one of the most well-known and widely used mathematical tools in the world. As a branch of optimization, it serves as the most important cornerstone of operations research, decision science, and management science.

This branch of study emerged when the American mathematician George B. Dantzig proposed the LP model and the simplex method in 1947. The computer, emerging around the same period, propelled the development of LP and the simplex method toward practical application. As a basic branch of study, LP orchestrated the birth of a number of new fields, such as nonlinear programming, network flow and combinatorial optimization, stochastic programming, integer programming, and complementary theory, and invigorated the whole field of operations research.

An outstanding feature of LP is its broad applications. Closely related to LP, a number of people have made pioneering contributions in their respective areas. In the area of economics, in particular, in 1973, Russian-American economist Wassily Leontief took the Nobel Economic Prize for his epoch-making contribution on quantitative analysis of economic activities. The academician L. V. Kantorovich of the former Soviet Academy of Science and American economist Professor T. C. Koopmans won the 1975 Nobel Prize for their optimal allocation theory of resources using LP. The same prize was also given to Professors K. Arrow, P. Samuelson, H. Simon, and L. Herwricz, several decades later when they paid close attention to LP at the starting days of their professional careers. In practice, on the other hand, the simplex method has achieved great success. Applications of the simplex method to the areas such as economy, commerce, production, science and technology, and defense and military affairs have brought about astonishing economic and social benefits. It is recognized as one of The Ten Algorithms in the Twenty Century (IEEE2002; see Cipra 2000).

Since W. Orchard-Hays worked out the first simplex-method-based commercial software, his implementation techniques were used and developed by many scholars, such as M. A. Saunders and R. E. Bixby. As a result, the simplex method became a powerful practical tool. However, the method is shown to be a non-polynomial-time one. In 1979, a former Soviet mathematician – L. G. Khachiyan proposed the first polynomial-time method, called "ellipsoid method." But unfortunately, it performed badly in computations and is not competitive with the simplex method. In 1984, an Indian mathematician – N. Karmarkar proposed another polynomial-time method. It is an interior-point method of lower polynomial order; it performed remarkably well in computations. The ensuing surge of research in interior-point methods has led to some very efficient interior-point algorithms for solving large sparse LP problems. During the same period, due to contributions on pivot rules made by P. M. J. Harris, J. J. H. Forest, and D. Goldfarb, among others, the efficiency of the simplex method made great progress as well, leading to an intense head-to-head competition between the two types of methods.

After more than 60 years since its birth, LP is now a relatively mature but rapidly developing discipline. Nevertheless, it is still facing great challenges. The importance of large-scale sparse LP models is nowadays enhanced further by the globalization. Everyday practice calls upon the research community to provide more powerful solution tools just to keep up with the ever-increasing problem size. This book attempts to respond to this reality and reflect the state of the art of LP by presenting the most valuable knowledge and results. It has been my long-lasting belief that research results, in operations research/management science in particular, should be of practical value, potentially at least. I therefore focus on theories, methods, and implementation techniques that are closely related to LP computation and hence applications.

This book consists of two parts. Part I mainly presents fundamental and conventional materials, such as geometric of feasible region, the simplex method, duality principle and dual simplex method, implementation of the simplex method, sensitivity analysis and parametric LP, variants of the simplex method, decomposition method, and interior-point method. In addition, integer linear programming (ILP), differing from LP in nature, is also considered in this chapter, not only because ILP models can be handled by solving a sequence of LP models but because they are so rich in practice as form a major application area of LP computation. Part II mainly covers the author's recent published and unpublished results, such as pivot rule, dual pivot rule, simplex phase-1 method, dual simplex phase-I method, reduced simplex method, D-reduced simplex method, criss-cross simplex method, generalized reduced simplex method, deficient-basis method, dual deficient-basis method, face method, dual face method, and pivotal interior-point method. The last chapter contains special topics, such as special forms of the LP problem, approaches to intercepting for primal and dual optimal sets, practical pricing schemes, relaxation principle, local duality, "decomposition principle," and ILP method based on the generalized reduced simplex framework.

To make materials easier to follow and understand, algorithms in this book are formulated and accompanied with illustrative examples wherever possible. If the book is used as a textbook for upper-level undergraduate or graduate course, Chaps. 1 and 3–6 may be used as basic course material.

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