PERGAMON

Mathematical and Computer Modelling 37 (2003) 1–17

MATHEMATICAL AND COMPUTER MODELLING

www.elsevier.com/locate/mcm

Box-Triangular Multiobjective Linear Programs for Resource Allocation with Application to Load Management and Energy Market Problems

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(Received and accepted September 2002)

Abstract—Models for multicriteria resource allocation are constructed with the specific box-triangular structure of a feasible region. The method of balance set equations is extended for the satisfaction level representation of the cost function space including the case of linearly dependent cost functions. On this basis, different goal criteria on the balance set are investigated for linear cases. Procedures for determining the balance set and finding goal-optimal Pareto solutions are illustrated on examples. The results of the paper are of universal character and can find wide applications in allocating diverse types of resources on the multiobjective basis in planning and control of complex systems including load management and energy market problems.

Keywords—MCDM, Resource allocation, Pareto solution, Balance set, Load management, Energy market problems.

1. INTRODUCTION

The methods of solving problems of allowable power allocation (or equivalent problems of power shortage allocation [1,2]) based on traditional principles of allocating resources [3], proportional allocation, optimal allocation, and inverse priorities, have substantial drawbacks. In particular, the use of the principle of proportional allocation leads to a tendency of overstating consumer demands while ignoring the necessity of maximizing their incomes or minimizing their losses [3,4].

*Research of this author was supported by the CNPq Grant No. 522916/96-1 (SU).
†Research of this author was partially supported by the NSERC Grant No. RGPIN-3492-00.

0895-7177/03/$ - see front matter Typeset by AMS-TeX
PII: S0895-7177(02)00319-9

When applying the principle of optimal allocation, such a solution is obtained that provides a maximum of total consumer income or a minimum of total consumer loss. However, the use of this principle also leads to a tendency of overstating consumer demands. The construction of damage functions is complicated, and they contain considerable uncertainties [1,2]. Besides, the idea of total income maximization or total loss minimization is questionable because of a possibility of unjustifiably discriminating against separate consumers in real situations [4]. The principle of inverse priorities is artificial and forces consumers to decrease their demands. This principle as well as other principles indicated above does not provide stimulating influences for consumers. Finally, when allocating resources or their shortages, it is necessary to take into account diverse consequences that cannot be reflected within the framework of traditional damage functions.

Significant improvement can be achieved in the framework of multiobjective optimization models [1,2,4] which allow one to consider and optimize diverse criteria in power allocation (or power shortage allocation) and to create incentives for consumers. This also relates to production, distribution, and resource allocation models which should be formulated as nonscalarized multicriteria problems. The same can be said about engineering mega projects design, see, e.g., [5].

The application of the multicriteria approach to resource allocation presents a new look at problems of load management [6] and problems generated by industry deregulation and restructuring [7] with a new, and more realistic content. In particular, market participants aspire to maximize their benefits (including economical, technological, ecological, social, and political factors). The goals of market participants, as a rule, come in conflict, which may be resolved by a compromise with the objective to create a mutually advantageous and harmonious solution for the problem.

The present paper is dedicated to solving allocation problems within the framework of multiobjective optimization models. The use of its results allows one to improve the validity and efficiency in allocating power or its shortages (real or associated with the utility of load management). The approach can serve as a methodological and computational basis for developing load management systems. The results are also applicable to energy market problems (dispatching strategies, contract market management, transaction congestion management, etc. [7]), and to allocating diverse types of resources (financial, water, computational, human, etc.) on the multiobjective basis in planning and control of complex systems.

The paper is organized as follows. In Section 2, a canonical form for general resource allocation, production, or power distribution problems is presented and transformed into a box-triangular mathematical programming problem. Simple consistency conditions are discussed and research objectives are listed. In Section 3, the linear case of the problem is considered and satisfaction level functions are described that do not disturb the linearity of the original problem and are convenient in practice especially for load management and energy market applications. Section 4 presents the transformation that allows us to express the balance set in terms of satisfaction level parameters (functions), then model examples are considered to illustrate the procedures for computing the balance set equations and transforming them into the satisfaction level representation. In Section 5, the case of linearly dependent cost functions is discussed. Section 6 presents various criteria formulated on the balance set and corresponding goal-optimal Pareto solutions. An algorithm is described that in regular cases converges to a certain goal-optimal Pareto solution in the state space, and conditions are presented to verify that this solution is, indeed, Pareto. An example for power shortage allocation computed with this algorithm is presented. Conclusions in Section 7 summarize the results of the research.

2. CANONICAL FORM OF RESOURCE ALLOCATION PROBLEMS

Resource allocation, production, energy distribution, and power shortage allocation problems are usually multicriteria and have the following structure: