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APPLICATIONS OF LINEAR PROGRAMMING

Dr. Kavindra Pal Singh*
Asst. Professor & Head- Dept. Of Mathematics, Upadhi Mahavidyalaya, Pilibhit

Abstract

The early applications of linear-programming methods fell into three major categories: military applications generated by the Air Force's Project SCOOP, interindustry economics based on the Leontief input-output model, and problems involving the relationship between zero-sum two-person games and linear programming. In the past few years these areas of application have been extended and developed, but the emphasis in linear-programming applications has shifted to the industrial area. In this section we shall describe in general terms many of these applications.

Keywords: *Scoop, Inter industry, Leontief, Emphasis.*

***Corresponding Author:**
Dr. Kavindra Pal Singh
Email: dr.kpsinghumv@gmail.com

Introduction

AGRICULTURAL APPLICATIONS

These applications fall into two categories: farm economics and farm management. The former deals with agricultural economics in the large, i.e., as related to the economy of a nation or region, while the latter is concerned with the problems of the individual farm.

One study in farm economics deals with interregional competition and the optimum spatial allocation of crop production in the United States. Efficient production patterns were specified by a linear-programming model constrained by regional land resources and national demands. The models used were based on 122 producing regions and included as many as 500 constraints, including upper bounds on each crop category within regions. Production patterns were indicated to allow minimum national food costs and alternatives in livestock feed substitution. Three models were used and a set of national supply prices for crops was derived for each. The quantitive analysis suggests the amount of land to be withdrawn from crop production and shifted to less intensive uses.

An application of linear-programming to a typical farm management problem is that of allocating limited resources such as acreage, labor, water supply, working capital, etc., in such a way as to maximize net revenue. The problem is to choose simultaneously the particular crop or crops to be grown in the following period, the number of acres of land to allocate to each of these crops, and the particular method to use in the production of each of these crops so that net cash return will be maximized. Another linear model of a more general nature considers the problem of the selection of a crop-rotation plan by an individual farmer. This application has been developed for both the static and dynamic situation.

MILITARY APPLICATION

One of the earliest linear models was that of the air-lift problem. Here the constraints involved the supplies to Berlin, number of runways available, number of crews and aircraft, and money available. The objective was either to deliver a specified number of tons at a minimum cost or to maximize tonnage supplied with a given supply of aircraft and money.

Another Air Force application, the aircraft-deployment problem, is concerned with the efficient allocation of limited resources such as combat aircraft and trained crews. Here we are given the numbers of aircraft to be produced in the successive months of a program. These aircraft are either deployed (sent into a combat area) or else used to train crews. Aircraft are deployed only when there are crew available to man them, and once deployed, they remain at the assigned station for the duration of the program. Aircraft sent to training may after a given number of months. Each aircraft in training produces a specified number of news crews each month. The object is to allocate the new aircraft between the combat and training missions so as to maximize the total number of aircraft-months of deployed aircraft.

The caterer problem is a paraphrased version of a military problem which arose in connection with the estimation of aircraft spare-engine requirements.

Other military examples include the problem of selecting an air weapon system against guerillas so as to keep them pinned down and at the same time minimize the amount of aviation gasoline used; a variation of the transportation problem that maximizes the total tonnage of bombs against disaster; and the solution of defence units used in a given attack to provide required protection at the lowest possible cost.

TRAFFIC ANALYSIS

This application deals with the problem of scheduling traffic signals. The mathematical formulation of a street-network system assumes knowledge of parameters such as: total traffic signals, cycle (red plus green), the fraction of the cycle that is red at each intersection, and the maximum number of vehicles that can move through the intersection in each direction. The model can handle such phenomena as variations in average speed along different portions of the route, turn-ibs abd tyrbidffs, variation in traffic capacity with intersection and flow direction, the capacity of blicks for holding stopped vehicles, three-way light or other special light schedules, delays in starting up after the light green and the appearance of random delays due to causes other than lights. The criterion for obtaining an optimum time phasing of the lights is that the number of delays be minimized.

TRANSPORTATION PROBLEMS

Discussions of the transportation problem and some of its variations are given in Chapter 4. The mathematical model of the problem has proved extremely versatile and versatile and susceptible to a number of computational procedures.

An associated problem is that of maximal flows in networks. For a network (e.g., rail, road, communications) connecting two links, the goal is to find a maximal flow from one given point to the other based on assigned capacities. Assuming a steady-state condition, find a maximal flow from one given point to the other. A simple computational method, based on the simplex method, has been developed for solving this problem.

In the second problem, products of exponentials are converted to sums of logarithms to provide a linear-programming approach to the syntheses of filter combinations for optimum fit of combination filters to a desired spectral-transmission curve. The unknowns to be determined could be either the concentrations of various possible filter constituents, which are to be mixed to form a single filter, or the thicknesses of various filters which are to be placed in series.

CONCLUSION

In addition to their wide application to physical situations, linear programming techniques have been firmly related to a number of theoretical areas of mathematics. Some of these disciplines have lent their power to the solution of special types of linear-programming problems. Additional applications include the efficient operation of a system of dams and the design of optical filters. The first problem is to determine variations in the storages in six Missouri River dams so as to maximize the energy obtained from the entire system and thereby increases the efficiency of operation. Physical limitations on the storages and releases appear in the form of inequalities. An approzimation to a change in energy is given as a linear function of the variations.

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