# A PRODUCTION PROBLEM INTERACTIVE PROTOTYPE OF LINEAR PROGRAMME

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In the paper we describe our approach in developing a new program package comprising different models of linear programming which all together build up a sophisticated system for production planning and decision making. By means of it the necessary information will be generated which the top management of Iskra enterprise, Ljubljana (one of the manufactures of electronic and computer equipment in Yugoslavia) is asking for. The input data are mainly retrieved from a data base and partly generated by means of a matrix generator. By generating different application matrices with different objective functions various production plans can be studied. The specific characteristics of the discussed production problem are (i) the need for balancing exports and imports and (ii) the ability to cope with a very high rate of inflation and very high rate of bank interest charges.

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## 1. INTRODUCTION

Optimization methods of manufactured assortments are generally not used frequently enough within the basic production process activities in most industrial establishments. Defined in a common linear programme form these methods could be particularly useful in those industries where they offer the market many different products or their variants and where the main proportion of the products, aimed for an unknown purchaser, is to be stored in a warehouse for a certain period of time (KRSTIČ, 3). There are two main reasons why the usage of the production problem linear programme has not been adequate within the establishments where it could have proved both possible and profitable. One reason is the lack of knowledge of optimization methods among the management who therefore are not in a state to draw and build up the necessary schemes and models of possible applications. The second reason is the rather awkward and demanding presentation of the LP input data and the complex interpretation of the LP output results which makes them hard to understand and explain to the end-users. Three years ago in the Iskra enterprise, Ljubljana, we drew up adequate models and organized the necessary education courses for end-users. We have been running on the computer some optimization methods for single members (factories) of the enterprise since then. Unfortunately all the computer programs are batch orientid and are not linked together with other parts of the information system, despite the use of some interactive equipment. This leads to a substantial redundancy in data within the Iskra information system.

A new programme package is being developed at present comprising different models of LP which all together build up a much more sophisticated system for production planning and decision making. By means of it the necessary fundamental information will be generated which the top management of a manufaturing company is asking for. The input data are mostly extracted from a data base and partly generated interactively by means of an application orientated matrix generator. By generating different aplication matrices with different objective functions, various production plans could be studied. The optimal solutions obtained by LP are further processed by a computer aided expert system. In the man-computer interface the most suitable production assortment is selected. Useful sugestions for the elimination of production bottle-necks and other complementary information could also be obtained. The management and planning functions that link together the financial and production parts are two important domains of the program system application.

The present LP program package, which is written in the APL programming language is of a prototype form. The final version will be in PASCAL. It solves linear programmes with up to 200 constraints and with up to 500 variables. The revised simplex method is applied where the basis matrix is presented in product form with spike selections. Great attention has been paid in order to make the package as user friendly as possible and less attention has been paid to the program's efficiency in execution.

In this paper we describe our approach and experience in developing the necessary software for solving LP in this particular field of application.

## 2. CHARACTERISTICS OF THE PRODUCTION PROBLEM MODEL

Let us first describe the general production (assortment) problem of linear programming.

Suppose that a company produces n products $P_1$, $P_2$, ..., $P_n$ by means of m different elements of the available production resources, such as machines, human capacities, financial means and other, the amounts of which are restricted by $b_1$, $b_2$, ..., $b_m$ within the discussed period of time. The consumption of each element of resources per unit of the produced product $P_k$ is known and we denote it by $a_{jk}$, for all j = 1, 2, ..., m and k = 1, 2, ..., n. There exist upper and lower production quantity bounds for each product due to the limited production resources, marketing restrictions (possibilities) and the signed contracts that impose certain obligations in production planning. The problem that arises most often is to define such an assortment and the corresponding quantities of the products which assure the maximum value of the profit after sale. Sometimes we try to optimize the net profit $c_k$ of product $P_k$, i.e. difference between its net selling price and its direct production costs.

Denoting by $L_k$ the lower, by $U_k$ the upper possible and by $x_k$ the optimum production quantity of $P_k$ we obtain

$$L_k \leq x_k \leq U_k \text{ , for } k = 1, 2, \ldots, n$$

or in a matrix notation

$$L \leq x \leq U$$

Similarly we may introduce

$$b = \begin{bmatrix} b_1 \\ b_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ b_m \end{bmatrix}, \quad A = \begin{bmatrix} a_{11} \cdots\cdots a_{1n} \\ a_{21} \cdots\cdots a_{2n} \\ \cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots \\ a_{m1} \qquad a_{mn} \end{bmatrix}, \quad c = [\, c_1, c_2, \ldots, c_n]$$

and define the general production problem LP in the following way:

Find (compute) the solution of production quantities vector x, satisfying relations (1) and

$$Ax \leq b$$

for which the value of the objective function f(x) is maximum, where

$$f(x) = (c,x)\,.$$

We can solve this problem by means of the general simplex method.

The specific characteristics of the production problem LP for the needs od the Iskra enterprise take into account the following two characteristics of the present state of the economy in Yugoslavia:

(i) The need for the closest possible balance between exports and imports within each particular enterpise

(ii) Very high rate of inflation and very high rates of bank interest charges (40 % - 70 %).

The possibilities of coping with the conditions that accompany the two characteristics differ very much among different enterprises. We explain here only briefly the basic characteristics of the foreign currency balancing assortment problem which incorporates both the resources and users of foreign currency at the same time. More details on the subject are given in (KRSTIČ and KLUČAR), 4).

The basic inequality which we add to the system of constraint functions is

$$\sum_{k=1}^{n} x_k \; (E-I)_k \geq D$$

where $(E-I)_k$ stands for the export - import trade balance of product $P_k$ exported to some foreign customer. The same product may differ in the export price E and the amount (price) of the imported raw material I from one country to another one. We therefore consider it in the LP as a different product for each different country. The values of the export - - import trade balance for all the products are stated in the same foreign currency unit, usually in DM or in US dollars. Product $P_j$ produced for the Yugoslav market would have a negative export - import trade balance $(-I_j)$, according to the above definition. D in the above relation means the necessary surplus in foreign trading which the enterprise needs for some other purposes such as the import of the necessary equipment, advertising in foreign countries and similar.

The example of treating each product as a different one for each diferent country shows that we have to deal with a large amount of LP input data (usually we optimize the production programme twice a year, accomplishing 3-4 consecutive computer runs each time and enabling the users to exchange some of the parameters). Here we use electronic spreadsheets as an additional and helpful resource for presenting the original data in the LP input form. Nevertheless we are nowadays not satisfied with this kind of approach. We have decided therefore to develop a new program package which is better orientated to the end-user. It is based on the results and experiences of the successfully performed production planning model adjusted to the real environment and giving reasonable financial effects both in Yugoslav and foreign currencies.

## 3. CHARACTERISTICS OF THE PRODUCTION PROBLEM INTERACTIVE-TYPE MODEL (PACKAGE) DESIGN

The discussed model (program package) consists of three modules:

- LP input data preparation module;
- LP module and
- postoptimization module.

In the following we describe the basic characteristics of each of these modules.

### 3.1. LINEAR PROGRAMME INPUT DATA PREPARATION MODULE

It consists of three parts that handle the following activities:

- retrieval of data from the Iskra enterprise MIS data base;
- interactive input and modification of the additional data;
- building up the LP input data matrix.

In order to retrieve data from the data base the user states the name of the product and the corresponding attributes that he wants. New products and new attributes can be added into the data base and modifications to the retrieved data (prices to-come, expenses, ...) can be performed interactively. The user can further state and define his conditions and demands with regard to restrictions on the production problem solution. He either accepts the already existing restrictions within the LP or imposes some new ones.

From the user standpoint there exist two ways (modes) of LP data preparation:

(i) The general mode which enables the common approach to the LP process definition (min of max value of the objective function, optional relation operators of the constraint functions, etc.).

(ii) A mode oriented solely towards the production problem LP. It is user-friendly approach with additional references (options) explaining the management view and demands on standards and the policy which should be taken into account within the production process optimizing procedures. The computer/user dialog includes questions and answers about the chosen objective function which should be added to the LP data matrix of the constraint functions. In a similar way the user also gets the list of existing and available production resources which he may use in the LP programme. Here too he may insert different relational operators.

### 3.2. LINEAR PROGRAMME MODULE

The most efficient methods for solving LP problems are different variants of the simplex algorithm. Due to the dimensions of our problem we could not use the standard simplex method. It was necessary to employ the revised simplex method with basis matrix in a product form (MURTAGH, 5). However, the expected dimensions of our problem don't require the use of the most sophisticated variants of this method. The most advanced feature used in our program is probably the algorithm for periodic refactorisation of the basis matrix with the "bumps and spikes selecting procedure".

We must mention, however, that this module programmed in APL shows relatively high inefficiency in execution compared with a similar FORTRAN program which is about ten times faster.

### 3.3. POSTOPTIMISATION MODULE

Similarly to the LP input data preparation module, the postoptimisation module enables two modes of operation. In the general mode, the common postoptimality (sensitivity) analysis is performed. It includes:

a) computing the intervals within which the values of particular coefficients of the objective function can range and yet maintaining the same optimal solution (providing all other elements remain the same),

b) computing the intervals within which the values of particular coeffiecients of the right-side vector b can range and yet maintaining the same optimal basis (with changed values of the basic coefficients of x).

Other standard types of LP output (MURTAGH, 5) are also provided.

For our particular application another mode of operation is available which is more user-friendly. It expresses all LP output data in terms of production and finance. Using this mode production bottle-necks because of technological constraints of foreign currency availability can be studied much more easily by the average end-user. Such interpretations also raise the level of user interest and expertise in LP models within Iskra.

## 4. PROTOTYPING APPROACH

We extensively used the prototyping approach when working on these problems. Prototyping (BOAR, 1) is a relatively new method for extracting, presenting and refining a user's needs by building a working, user-friendly model of the ultimate system quickly and in context. The prototyping approach, by incrementaly refining the model, leads to a better understanding of the problem and hence helps in the development of effective and efficient solutions.

There are four basic stages in the prototyping life cycle:

(i) Identify user's needs - define the problems and define the functions and data needed to solve them.

(ii) Develop an interactive model - quickly create a preliminary working model that incorporates the key items identified in the previous step.

(iii) Demonstrate the interactive model - while demonstrating the small system encourage the active role of the user - to add to and improve the system.

(iv) Revise and evaluate the system - the prototype is alternately revised and implemented in the user's environment until the system is acceptable to both users and developers.

For prototype building we use the APL programming language. This is a high level language which is particularly useful for the quick development of interactive programmes (GILMAN, ROSE, 2). Its ability to perform vector and matrix operations make it also a powerful tool for testing mathematical algorithms. The main obstacle for wide use of APL is its inefficiency in execution. Nevertheless APL proved to be very useful as a prototyping language for our particular type of application. We feel that our APL based prototype is a very good basic bor the development of a production solution, which will be in the PASCAL language.

## 5. CONCLUSION

Our project to build an LP production problem interactive prototype is not finished. Up to now our main attention was devoted to building an adaptively designed optimization model and appropriate LP module. The data preparation module and postoptimisation module are not yet fully integrated into the system.

The experience obtained in solving production problems for both particular factories and the whole enterprise has encouraged us to continue and expand this project.

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