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# Operational Production Programming within the Concept of an Integrated Information Processing System (Application at "Danubiana" Tyre Factory)

*The present technologies are developed and achieved to be managed and checked by methods of operational research and by means of electronic computers. In the absence of these methods and means, we "consciously" give up the advantages of these technologies.*

## 1. INTRODUCTION

The complexity of the production programming problem in industrial concerns depends to a great extent on the finished product structure. The greater the diversity of the semi-finished products, the more complicated the manufacturing process and the more complex the production programming problem.

For a proper production development, more precisely, for using all capacities and providing all raw materials, materials, and semi-finished products in due time, a consistent, precise and operative set of programs is absolutely necessary.

A production programming system must take into account all existing conditions in the factory and be sufficiently operative in order to let these conditions be reflected in the resulting production programs.

The „Danubiana" factory has a yearly production of 1,500,000 tyres of different sizes, starting from tyres for light passenger cars, up to heavy truck and tractor tyres. The factory's technical equipment is up-to-date,

the location of machines flow of materials within the operating process, respectively, conform to the functional needs. Under these conditions the designing of an information processing system was considerably facilitated.

## 2. SYSTEM'S REQUIREMENTS

The concept of designing an integrated production programming system was based upon the principle of using an electronic computer, with the help of which all necessary data could be stored of files, to be used in an economic-mathematical model whose solutions could be quickly obtained, and which would make up optimized production programs (Fig. 1).

Accordingly, a model was drawn up which, when using operational research methods, could allow the creation of production programs, thus achieving three activities closely linked among them together:

a) calculation of the requirements of raw materials, supplies and half-finished products;

b) scheduling;

c) equipment management.

The model uses data recorded on a file system which, by means of computer programs, is permanently updated, thus reflecting production situation in the factory.

Within the analysis of the production programming activity in the previous system (which was manual) it was established that, in order to achieve the integrated programming system, the mathematical model must answer the following requirements:

I. Yearly and monthly planning being available, one must make provision for the necessary amounts and terms, related to the finished products of a great number of items, representing raw materials, materials, semi-finished products (assemblies and subassemblies).

This is what is called the calculation of requirements. The aim is to provide the material for the manufacturing program of the finished product.

The objectives of the research is to find a fast and accurate method of performming all necessary computations, of modifying them according to changes occurring in the production plan, and taking into account the actual production and modification in the plan.

For such a subsystem to be efficient, it must perform the following tasks:

— accurate determination of finished product amounts (tyres according to various specifications) which must be delivered;

— determination of net gross requirements in components (mixtures, plies, tyre treads, etc.);

— determination of semi-finished product lots;

— determination of ordering data for supplies, in accordance with re-ordering or manufacturing cycles;

— fast carrying out of modifications in tyre production programs, according to various specifications;

— updating of the plan, depending on considerations external to the system;

*A GENERAL SCHEME OF AN INTEGRATED SYSTEM OF OPTIMAL PRODUCTION*
*(AN APLICATION AT DANUBIANA TYRE FACTORY)*

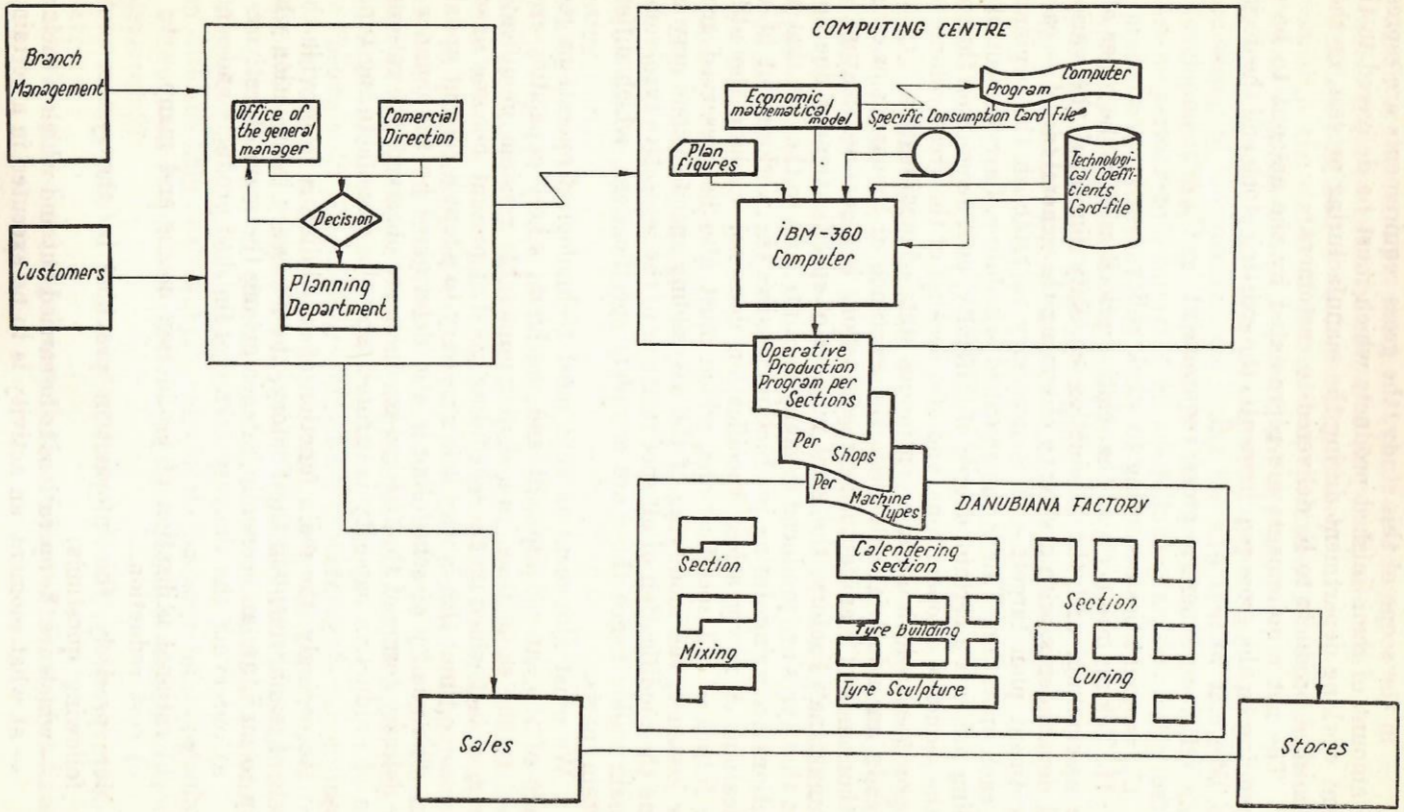



**Fig. 1**

— in the scope of this study, the gross requirements are represented by the amount of semi-finished products which must be delivered to the subsequent working department during the manufacturing process, or the amount of finished products to be delivered to customers.

The net requirements are represented by the amount to be produced depending on the gross requirements, the existing stock and the desired stock.

We can write:

Net requirement = gross requirement $\pm C_{ps}$

where

$C_{ps}$ = quantities according to stock policy.

II. Taking into account the relative priorities (e.g. the order of entering the assembling) and the production capacity limits of the various shops and departments, with a view to observing the general target — carrying out assortment plan targets — it is necessary to establish the beginning terms for each operation. This is the so called scheduling. Carrying out of the scheduling presents a certain degree of difficulty, as it depends on the complexity of the sequence of operations, and also because of the great volume of data to be processed, which are in a continuous state of modification.

In an industrial enterprise the existence of thousands or even of tens of thousands of manufacturing specifications is a common feature. With the „Danubiana" Factory, the great number of specifications is due both to the fact that tyres are produced in many variants, and to the fact that any modifications occurring during production requires the working out of a new specification. A newly arised specification does nor exclude the utilization in the future of old specifications, which must also be preserved accordingly. For instance, the modifying of the assembling specifications may not determine the modification of all specifications of the respective tyre, some of them remain valid; hence there are complete specifications, which differ only in certain parts.

We must also mention that most technological operations require the usage of the same equipment and machines, whose capacities are limited.

At the same time, in a shop innumerable random modifications may occur, a fact which makes scheduling good at present become unserviceable after some time; this is why it is necessary to adopt a current updating solution. The quality of scheduling is also determined by the manner in which the delivery terms of the finished products are observed, the rational utilization of production capacity is ensured, and the manufacturing time is minimized.

Accordingly, the main function of scheduling is to provide the various levels of management in the Factory, the necessary information which could help to maintain an economic balance among the main objectives:

a) observing the delivery terms of finished products and semi-finished products;

b) rational utilization of production means and manpower;

c) cost reduction.

More precisely, the information provided by the system must answer the following questions:

— which are the operations to be carried out and which is their sequence;

— at what moment an activity is to be executed in a certain shop;

— which is the relative priotity of each operation;
— which machine must be prepared for work, and when;
— which is the load of each working place;
— which is the status of the various operations already programmed;
— what supplementary activities are necessary.

III. The optimal production management requires obtaining and operative processing of information concerning the situation of the production process development in every shop and in every working place. The management must be permanently informed on the following aspects, reflected within the production program:

— which is the status of the equipment;
— what is the load on the working place;
— which is the development stage of work in the execution lots.

### 3. FILE SYSTEM

For the mathematical model to fulfil the above mentioned requirements, a file system was created which, together with a program package, provides the necessary (input or processed) data.

Files are stored upon direct access storage devices (magnetic disks, with IBM 360/40 computer).

There are two file categories:

a) technical files;
b) factory order files.

Technical files are as follows:

item master file;
production structure file;
routing file;
working place file.

The package programs allow to create files on the basis of delibered initial data, and to update these files. Data, more precisely modifications, do not arrive at a single place; any change is delivered to the system and, with the help of subprograms, is operated in all files and in all recordings, referring to the information being modified. Consequently, the files offer any time, the true picture of the whole production process, all information appearing uniquely and in accordance with the last modification.

*The Factory order file* contains information concerning the factory orders and the quantities of materials available, where they can be provided from, in what conditions and when. This file is also updated. At the same time, in this file the reduction of the planned quantities, according to the quantities already manufactured, is calculated.

Also with the help of the subprograms in the package following supplementary information is obtained (besides the information necessary to production programming):

— lists of immediate components of an assembly, with the required quantities;

— intended parts lists, together with the amounts building up a finished product;

— list of the requirements of raw materials for a finished product or a finished product group;

— manufacturing specifications of products, at all levels (shops, machines), according to current modifications;

— list of semi-finished products, affected by a certain modification;

— modification of material expenses in the costs, due to a change of technology.

## 4. BUILDING UP THE MATHEMATICAL MODEL

As in any optimizing problem which uses linear programming, the model must be built in such a manner, as to let the objective function determine solutions satisfying the proposed goal. Many times, instead of the objective function, a pseudo-function can be introduced, whose maximum or minimum be equivalent with the optimum of a function, which parhaps could not be made linear.

In the case of the „Danubiana" Tyre Factory, production programming must satisfy, more precisely, balance divergent tendencies:

I. Tendency of satisfying the assortments plan, which prescribes the manufacturing af all stipulated assortments, at compulsory terms.

II. Tendency of the departments with continuous fabrication, which are interested in producing lots as large as possible, of the same semi-finished product, i.e. to allow as few changes as possible.

III. Tendency of the departments with discontinuous fabrication which are interested in constantly manufacturing all possible assortments in parallel.

The tendency to satisfy the production plan is the main one, and it will decisively determine the program. With a view to obtaining a global optimum, a balance will be sought for, between the interests of the two groups with continuous or discontinuous fabrication.

A department is considered to have continuous fabrication, when its production is carried out in the series-linking system. In other words, a certain product type precedes or follows after another product type, but they are by no means manufactured in parallel, and the shutting down of a machine results in the stopping of the production of the whole department, for all types of products. For instance, calendering is carried out by means of a high output machine; shutting down this machine results in stopping all production for this type of semi-finished products. Changing the "cord" type requires shutting down the unit, and the lot to be calendered must be sufficient until resuming the process for the respective type.

Discontinuous production is considered to be carried out with machines or machine groups, working in parallel and independently. Shutting down a machine does not results in stopping all production, but it merely diminishes production. The decrease can be avoided if there are reserve machines, and this is not possible with continuous departments. The optimal working rate is obtained when raw materials, or the produced semi-finished products, respectively, are always in sufficient amounts. The problem of providing these amounts is a stock problem; yet space and technological restrictions do not

allow ideal stocks. We could state that this is the source of contradictions and, of course, of the difficulties arising when drawing up an optimal working program.

The mathematical model reflects this state of things. Restrictions are divided into theree categories:

I. Restrictions of departments with continuous fabrication, of the form

$$\sum_j a_{ij}x_j \leqslant b_j \qquad i = 1, \ldots, K_1$$

where $a_{ij}$ are time consumptions, for every finished product type, from the total working time of the machine or machine group. Generally, in these restrictions, every finished product is represented in every inequation, due to the continuous character of production.

II. Restrictions of departemnts with discontinuous production have the form

$$\sum_i a_{ij}x_j \leqslant b_i \qquad i = K_1 + 1, \ldots, K_2$$

Coefficients $a_{ij}$ represent the time consumption of the machine ensuring the production. The characteristic of these restrictions is the fact that, in an inequation, only these products (these coefficients) appear, which are fabricated by this machine. This meanes that, for the curing department, where the mould is unique for a type of product, we have a single coefficient differing from zero in an inequation.

III. The group of restrictions, related to the monthly plan, has the form

$$x_j \leqslant b_{j+K_2} \qquad j = 1, \ldots, K_1$$

The objective function has the form

$$f(x_j) = {}_jC'_ix_i$$

where $C'_i$ represents the cost of the down-time of machines during the manufacturing of a product. This function must be minimized, as

$$min\ f(x_i) = max(-f(x_i))$$

We shall minimize function $\sum C'_ix_i$, but

$$C'_i = T - C_i$$

where $T$ is the total time, which is constant, and $C_i$ is the utilization time of machines.

We get:

$$\sum C_i' x_i = \sum C_i x_i - K$$

where $K = T_i$

Hence, instead of minimizing function $\sum - C_i' x_i$, we shall minimize function $\sum C_i x_i$.

## 5. CREATION OF PRODUCTION PROGRAMS

In order to create production programs, one executes on the computer a subprogram package comprising (Fig. 4):

SP1 — Subprogram of monthly program analysis;

SP2 — Subprogram of production capacities allocation;

SP3 — Subprogram of machine loading optimization;

SP4 — Computation subprogram for the fabrication of requirements;

SP5 — Subprogram of editing fabrication programs.

In the first stage one carries out the analysis of the plan provided by the plan and sales department, obtained from the plan file, compares it with possibilities of execution, according to data in the technical files. Following the obtained results, the monthly plan is conveniently modified.

The final plan is once more analyzed from the viewpoint of critical assortments. An assortment is considered as critical when, in order to produce the amount stipulated for a certain term, the manufacture of a minimal daily amount is compulsory.

Further on, the daily production program for the whole month is computed, and programs are edited for departments, shops and machine groups (Fig. 2,3). Following two special printed forms are edited, i.e. the production development graph (meant for the management, to follow up production) and the graph of mounting and dismounting moulds for the curing presses.

Production programs may be edited for the whole month, or for a certain time period.

When production programs are complied with, i.e. when the achievements are close to the planned figures, programs remain definitive until the end of the month. If the accomplishments deviate from the planned figures, reprogramming becomes necessary, and new production programs will be computed and edited. The same thing happens when, during the month, there appear plan modifications or when certain production capacities change (stoppages or lack of supplies).

Printed forms containing production programs are concomitantly reporting forms for the achieved production, and in this way the number of documents in circulation through the factory is diminished.

## Working out of Production Programs

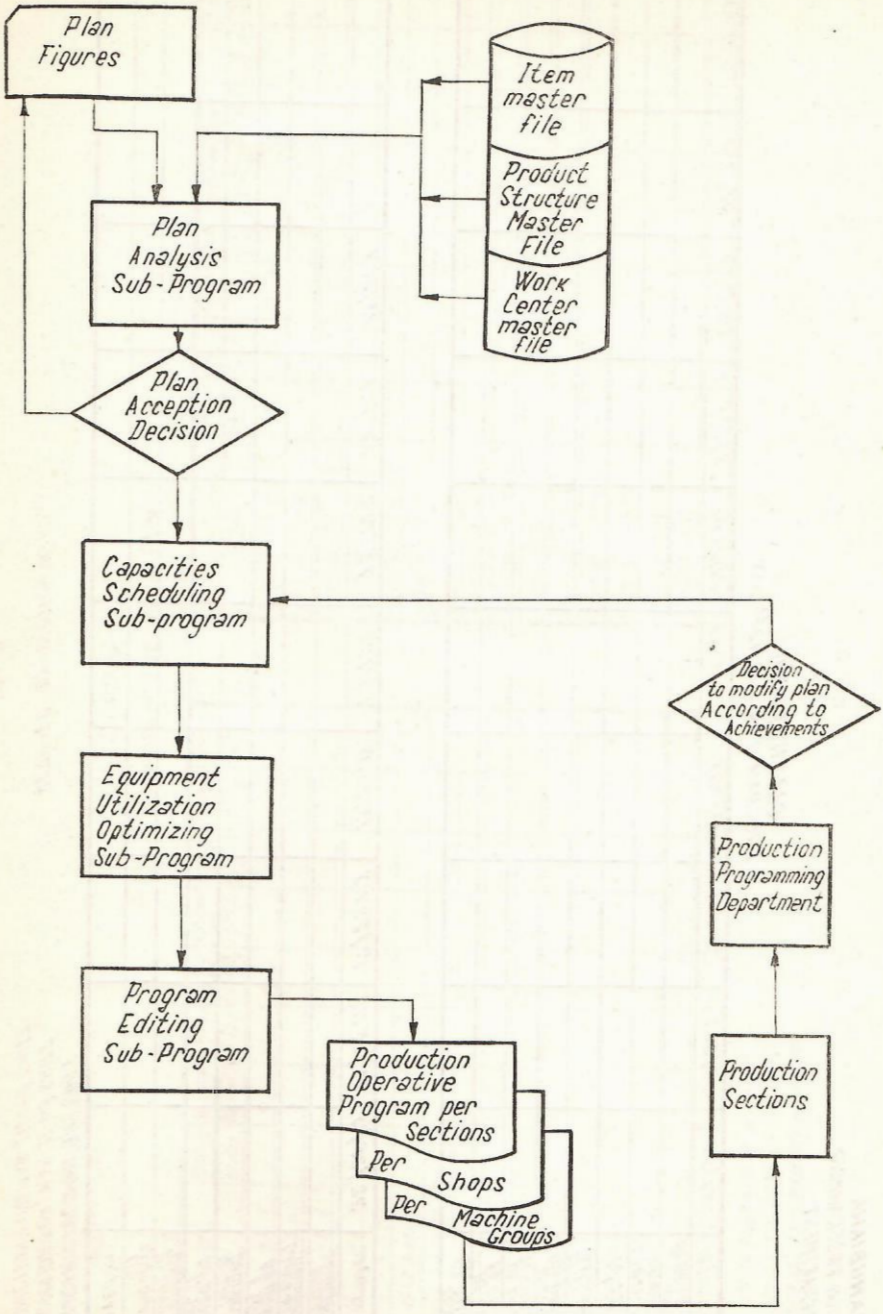



Fig. 4

DANUBIANA
PRODUCTION PROGRAMMING
DEPARTMENT

## CALENDERING
### PROGRAM FOR THE 12th DAY

| Item number | 25/35 V | 25/34 V. | 20/25 V | 13/20 V | 25/30 NY | 25/34 NY | 33/35 NY | 25/30 V | 20/30 V | 21/35 NY |
|---|---|---|---|---|---|---|---|---|---|---|
| Programed by day | | | | | | | | | | |
| Programmed for shift I | | | | | | | | | | |
| Achieved by shift I | | | | | | | | | | |
| Programmed for shift II | | | | | | | | | | |
| Achieved by shift II | | | | | | | | | | |
| Programmed for shift III | | | | | | | | | | |
| Achieved by shift III | | | | | | | | | | |
| Achieved by day | | | | | | | | | | |

| Item number | 22/25 NY | 21/25 NY | 17/20 NY | 13/20 NY | 115/COR | 75/PBR | 33/PDR | 13/30 Y | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Programmed by day | | | | | | | | | | |
| Programmed for shift I | | | | | | | | | | |
| Achieved by shift I | | | | | | | | | | |
| Programmed for shift II | | | | | | | | | | |
| Achieved by shift II | | | | | | | | | | |
| Programmed for schift III | | | | | | | | | | |
| Achieved shift III | | | | | | | | | | |
| Achieved by day | | | | | | | | | | |

PRODUCTION FOREMAN I-st SHIFT
PRODUCTION FOREMAN II-nd SHIFT
PRODUCTION FOREMAN III-rd SHIFT

VERIFIED BY SECTION HEAD

Fig. 3

"DANUBIANA"
PRODUCTION PROGRAMMING
DEPARTMENT

# CURING

## PROGRAM FOR THE 14th DAY

| Type and Size | Programmed by day | Programmed for shift I | Achieved by shift I | Programmed for shift II | Achieved by shift II | Programmed for shift III | Achieved by shift III | Achieved by day |
|---|---|---|---|---|---|---|---|---|
| 6.40-13 4 S V | | | | | | | | |
| 6.40-13 T 4 S NY | | | | | | | | |
| 6.40-13 T 4MS V | | | | | | | | |
| 6.45-13 4 S V | | | | | | | | |
| 6.45-13 T 4 S NY | | | | | | | | |
| 6.45-13 T 4 MS V | | | | | | | | |
| 7.00-13 4 S V | | | | | | | | |
| 7.00-13 T 4 S V | | | | | | | | |
| 7.00-13 T 4 MS V | | | | | | | | |
| 6.95-14 T 4 S NY | | | | | | | | |
| 6.95-14 T 4 MS V | | | | | | | | |
| 7.00-14 T 6 S V | | | | | | | | |
| 6.00-15 LT 4 MS V | | | | | | | | |
| 6.00-15 LT 4 S V | | | | | | | | |
| 6.70-15 6 S V | | | | | | | | |
| 6.50-15 6 MS V | | | | | | | | |

| Type and Size | Programmed by day | Programmed for shift I | Achieved by shift I | Programmed for shift II | Achieved by shift II | Programmed for shift III | Achieved by shift III | Achieved by day |
|---|---|---|---|---|---|---|---|---|
| 9.00-16 12 I V | | | | | | | | |
| 9.00-16 12 S V | | | | | | | | |
| 7.50-20 12 I NY | | | | | | | | |
| 7.50-20 12 S NY | | | | | | | | |
| 8.50-20 12 S NY | | | | | | | | |
| 9.00-20 12 S V | | | | | | | | |
| 9.00-20 12 T NY | | | | | | | | |
| 10.00-20 12 S V | | | | | | | | |
| 10.00-20 12 T NY | | | | | | | | |
| 11.00-20 12 S V | | | | | | | | |
| 6.00-16 12 NY | | | | | | | | |
| 12.00-38 12 NY | | | | | | | | |
| 14.00-38 12 NY | | | | | | | | |
| 12.4-28 12 V | | | | | | | | |
| 9.5-36 12 V | | | | | | | | |
| 14.9-38 12 V | | | | | | | | |

PRODUCTION FOREMAN I-st SHIFT
PRODUCTION FOREMAN II-nd SHIFT
PRODUCTION FOREMAN III-rd SHIFT

VERIFIED BY SECTION HEAD

Fig. 2

## LA PROGRAMMATION OPERATIVE DE LA PRODUCTION DANS LA CONCEPTION D'UN SYSTEME INFORMATIQUE INTEGRE
### (applications à l'Usine de pneumatiques "Danubiana")

La production industrielle implique une discipline des activités. Plus les produits ont une structure plus compliquée et plus ils sont en grand nombre, plus le maintien de la discipline est difficile. En premier lieu on doit établir un ordre rigoureux qui réponde aux nécessités à caractère technologique, d'organisation et économiques.

L'utilisation d'un calculateur électronique et des méthodes de la recherche opérationnelle a permis l'élaboration d'un sous-systhème (qui sera inclus dans un systhème intégré) de programmation de la production pour l'usine d'enveloppes "Danubiana" de Bucarest.

Le modèle mathématique dont les solutions sont des programmes journaliers de production pour toutes les sections, représente les conditions d'organisation de l'usine, et la fonction d'efficience détermine le choix des solutions qui assurent l'utilisation au maximum des capacités de production et la réalisation des chiffres de plan et du plan d'assortiment.

## ОПТИМАЛЬНОЕ ПРОГРАММИРОВАНИЕ ПРОИЗВОДСТВА В УСЛОВИЯХ ИНТЕГРИРОВАННЫХ СИСТЕМ ЭЛЕКТРОННОЙ ПЕРЕРАБОТКИ ДАННЫХ (ПРИМЕНЕНИЕ НА ЗАВОДЕ АВТОПОКРЫШЕК «ДАНУБИАНА»)

Промышленное производство требует дисциплины деятельности. Чем более сложную структуру имеют виды продукции и выпускаются в большем количестве, тем более трудно поддерживать эту дисциплину. Прежде всего, необходимо установить строгую очередность, соответствующую потребностям технологического, организационного и экономического характера.

Применение электронных вычислительных машин и методов операционного исследования позволило составить подсистему (которая будет включена в интегрированную систему) программирования производства на Бухарестском заводе автопокрышек «Данубиана».

Математическая модель, решения которой являются суточными программами производства для всех цехов, представляет собой технические и организационные условия на заводе, а функция эффективности определяет выбор решений, обеспечивающих наиболее полное использование производственных мощностей и производительных сил и выполнение плановых задач количественного и качественного характера.