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On the Production-Control Systems Design

"Economic and industrial activities are closed-loop, information-feedback systems"

Jay Forrester:
"Industrial Dynamics" (1961)

1. Introduction

The study of management information systems is probably the most important and challenging area of computer science at the present time.

In contrast to procedural compilation, where new systems are little more than minor conceptual modifications of prior systems, management information systems are still in an era of major qualitative change.

The nonprocedural aspects of the existing management information systems are dramatically disparate and new systems designs are required to reach a system that performs all the necessary functions in an excellent fashion.

The computer literature is rich with potential and planned schemes to improve managerial performance, but many are in the early stages of what might prove to be a lengthy evolution.

The label "management information system" is being used in connection with data-processing applications with the main purpose to provide operational control of a set of records. A set of rigid routines provide exception reports for some applications and enable "one-time" queries to search the file for specific information to assist in policy decisions.

The management-information system is designed to give manageres predigested information not raw date. Instead of daily reports, pertinent abstracts are provided when the need arises. Many of the reports reflect the fact that an aproximation today may be of more use than precision tommorow.

Modern management information systems provide more than simple maintenance and display of data bases; they also assist in decision-making by performing more complex processing on their stored data. The label "decision-making" is being used in connection with information translation into action.

The system handles two classes of decisions automatically:

— those for which the rules are known;

— those for which a policy has been developed.

In many ways it is not so much an information system as a "control" system, taking data from on-going processes and evaluating them to determine what actions to take to adjust the processes to their goals.

The studies made in a big number of industrial enterprises during the last few years have created the necessary conditions for elaborating a unitary conception on the production control system.

By production control we mean the drawing up of the production plans of the different subunits of the enterprise on short periods of time (month, decade, shift) and the calendar control of production. The main task of the control is to lay out the plan targets on production subunits and on time, so as to ensure a rhythmic activity. In the last analysis, an effective control system must permanently identify the reserves of production capacities and systematically mobilize them.

One of the important stages of scheduling is the spacing out of the plan targets of the enterprise on its various component sections. The object of planning within this stage is the product, the subunit or part.

Generally, for establishing the plan targets of the sections, one sets out from the quantity of finished production which has to be delivered; going in the reverse order of the production process, on sections, and taking into account the change in the unfinished production stock, the quantity of production which has to be launched is being established.

The method of outrunning is used for the calendar planning of the plan targets and for the drawing up of the production programs: by outrunning, we mean the time interval between the term for the beginning of work as related to the term for the start of another work linked between them by a common technological process. The rhythmic non-fulfilment of the plan in a section or workshop is leading to the rhythmic chain non-fulfilment of the production plan at all subunits which continue to participate in the technological process. The importance of the unfolding of a rhythmic activity of production in all sectors determines the importance of the production control system.

Scheduling represents the activity in which the order of execution of each operation is established — the object on work place, taking into account the existing production capacity and the necessary manpower and observing the terms for the delivery of products. The scheduling activity can be viewed as a control activity of a decision unit.

2. The concept of control system

Before proceeding with the specific details of equations and a suitable mathematical structure for a dynamic model, we shall discuss some general principles that should guide the construction of a production control system.

A production policy can be specified in either of the following two manners:

— open loop policy
— feedback (closed-loop) policy.

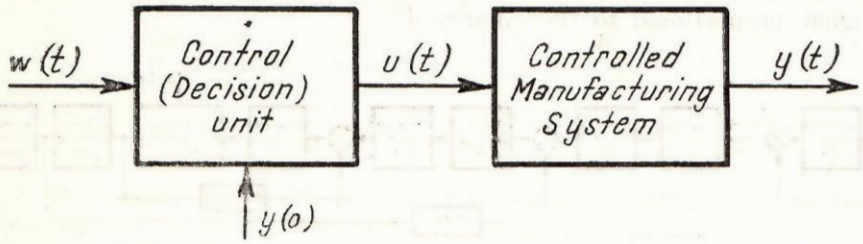

Fig. 1

The production policy is called an open-loop policy if the controlled input $u(t)$ is specified as a function of the reference input $w(t)$ and only the initial state of the output $y(o)$ (Fig. 1):

$$u(t) = f_1(y(o),\ w(t),\ t)$$

The production policy is called a feedback policy if the controlled input $u(t)$ is specified as a function of the reference signal and the current state of the production system (Fig. 2):

$$u(t) = f_2(y\ (t),\ w(t),\ t)$$

A policy indicates how $u(t)$ is to be generated from w and y. A feedback policy is usually the preferred mode of operation for production systems, because feedback operation tends to make the system less sensitive to variations of the production system parameteres and makes use of the most up-to-date information on the state of the production system. Therefore, if a disturbance of the system occurs in the feedback case, the system ope-

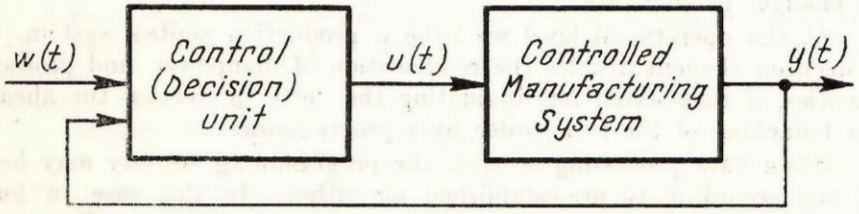

Fig. 2

rates on the latest measurement of $y(t)$. In the open-loop system, however, the entire input is programmed on the basis of an intial-state value. There any subsequent disturbances of the output destroy the optimality of operation.

Figure 3 represents a general feedback production control system.

There are many feedback loops chained according to the decision levels in the industrial system.

The command is an input which is developed externally and is independent of the feedback control system. The reference input units produce a signal proportional to the command.

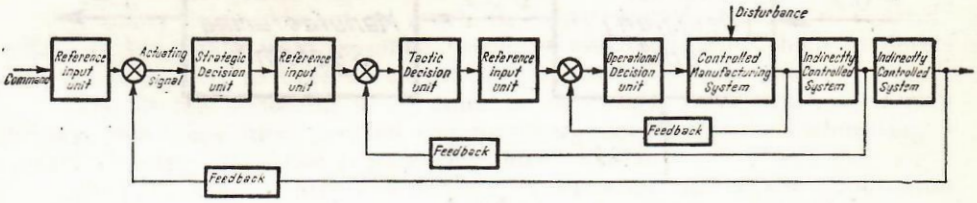

Fig. 3

The feedback is a signal that is a function of the controlled variable and is compared with the reference input in order to obtain the actuating signal. The actuating signal equals the difference between the reference input and the feedback. The control elements develop the manipulated variable from the actuating signal. The manipulated variable is the quantity obtained from the decision units and applied to the controlled system. The disturbance represents undesired signals that attempt to affect the value of the controlled variable. The feedback elements produce the feedback from the controlled variable.

We limit our discussion here to the operational level, considering only the first inner closed-loop system.

The input indices from the planning activity (tactic decision) are compared to the actual output. The closed-loop control system drives the output until it equals the input and the error is zero. Any difference between the actual and desired output must be automatically corrected. Through proper design, the system can be made relatively independent of secondary inputs and changes in structure.

At the operational level we have a production control system. Here the decision element decides the re-allocation of manpower, and production capacities, if they exist, for liquidating the delay or decides the ahead-of-term launching of the next order by reprogramming.

When data processing is used, the programming activity may be carried out according to pre-established algorithms. In this case, a human decision element establishing changes, the programing places in the reaction loop of the closed-loop system. It is known however, from the theory of feedback systems that the sensitivity of the closed-loop systems is manly determined by the input elements and by those on the feedback loop.

Sensitivity is a measure of the dependency of a system's characteristics on those of a particular element.

If we denote:

Pl — the transfer function of the reference input element;

S — the transfer function of the direct path in the closed-loop system;

U — the function transfer of the feedback path;

I — the Laplace transform of the input;

Pr — the Laplace transform of the output;

the system's transmittance is.

$$T = \frac{Pr}{I} = \frac{Pl \cdot S}{1 + US}.$$

The sensitivity of the system's transmittance with respect to the characteristics of the element U:

$$\sigma_U^T = \frac{\frac{dt}{T}}{\frac{dU}{U}} = \frac{U}{T} \cdot \frac{dT}{dU}.$$

Where:

$$\frac{dT}{dU} = \frac{-Pl^2 \cdot S^2}{Pl(1 + U \cdot S)^2}.$$

Then:

$$\sigma_U^T = -\frac{U}{T} \cdot \frac{T^2}{Pl} = -\frac{U \cdot S}{1 + U \cdot S}.$$

For cases where $U \cdot S \gg 1$, this reduces to $\sigma_U^T \approx -1$.

It is important to note that an ideal system has zero sensitivity, i.e. the feedback loop is directly reflected in an overall system transmittance change. The elements used for the direct path must therefore possess precise and stable characteristics. Thus, it is desirable to replace the human decisional element on the feedback loop.

A production control system is a control system that keeps the outputs of the production process near the desired outputs in the presence of disturbances.

It consists of;

— sensors that measure the output;

— a decision unit that receives transduced signals from the sensors and computes control signals;

— effectors that receive the control signals and produce corresponding control actions.

We limit our discussion here to the design of the *logic* for the decision unit, and assume that the system to be controlled can be modelled as a stationary dynamic system.

Over the past few decades a vast amount of research has been expended on feedback control theory and its application to the design of multi-

variable control systems. One unfortunate aspect of the situation which has resulted from the enormous body of literature which has been produced is that the underlying unity of the subject has become obscured, and it has become increasingly difficult to relate some recent theoretical developments to the basic ideas of classical feedback theory and to the needs of practising design.

Unfortunately during that time semantic, symbolic, and conceptual misunderstandings between engineer and economist have greatly impeded a cross-fertilization process which otherwise might lead to important results.

The dynamic relationship between the inputs and the outputs of the controlled process in vector state-open form may be described by a state equation of the form:

$$x = f(x,\ u,\ t)$$

$$y = g(x,\ t)$$

where u is a $m \times 1$ control vector

x is a $n \times 1$ state vector

y is a $p \times 1$ output vector

The time behaviour of the controlled process is described by the solution to this equation. Convenient terminology for the solution, or motion, is:

$$x(t) = \psi_u(T,\ x,\ t_0)$$

This equation is to be interpreted as the motion of $x(t)$ observed at time T after starting at time t_0 in state x, and influenced by the control input u, which is defined for the interval t_0 to T.

The state of the system is simply defined as the minimum set of variables, denoted by $x_1, \ldots, x_n$, which, together with the given inputs $u_1, \ldots, u_m$ determine the outputs $y_1, \ldots, y_p$ at any time $t > t_0$.

One of the most common requirements in the synthesis of control systems is that some components of the output vector must be driven asymptotically close to any given constant reference vector w (that is with null steady state error) if u is constructed as a linear combination of all output variables, i. e.:

$$u = K(w - y)$$

where:

$$K = [k_1, \ldots, k_p]$$

then,

$$x = A_x + B_n = (A - BKC) \times + BKw$$

By choice of the vector k the eigenvalues selection must be done with some judgement so that the required values of u are indeed available.

However, a conventional feedback control system is not capable of high performance in the presence of extreme changes of the controlled system's parameters and large external disturbances.

In order to achieve a desired response, an adaptive control system is needed. Such a feedback control system can be considered to be composed of the following stages of operation [1]:

— continuously compare the desired performance of the system with actual system performance;

— automatically and continuously, adjust the k parameters in order to minimize the difference between desired and actual system performance.

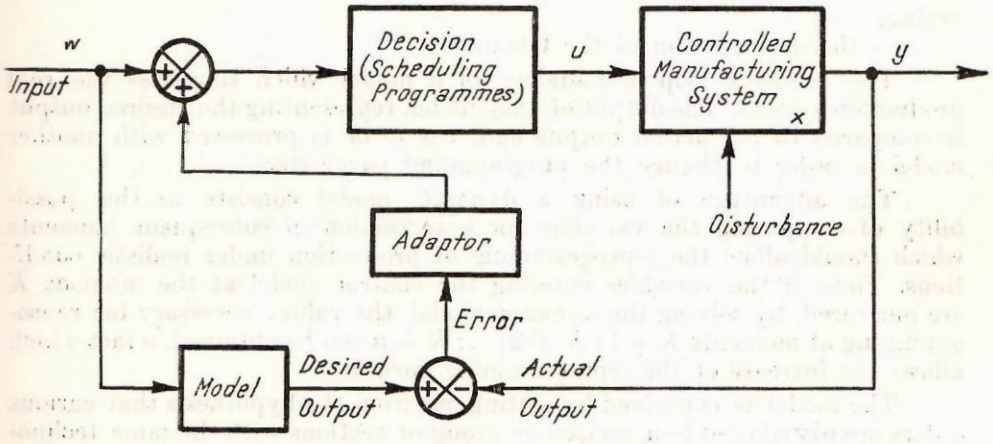

Fig. 4

In other words, if the industrial system changes its parameters, the control system should automatically change the decision.

The block diagram of a model-reference adaptive control system is shown in Fig. 4.

The elements that change the conventional feedback control system to an adaptive one are the addition of the model, compa rator and adaptor. The model-reference adaptive control system applies the input to both the conventional feedback control system and the model, whose output represents the desired or optimum response. If a difference exists between the actual and desired responses, an error signal is generated by the comparator. The resulting error signal is then operated on by the adaptor in an apriori fashion in order to adjust the control (decision) unit, which attempt to achieve optimum control. The model furnishes this system with an optimum criterion for adaptivity. Any changes caused by variations of the parameters of the controlled system or external disturbances are compensated for by the adaptive feature.

From what has been presented so far, it is obvious that adaptive control systems always have the following two characteristics present:

— identification

— actuation

Identification refers to the measurement of the characteristics of the control systems to be optimized. Actuation refers to the generation of a

command which varies some parameters in order to optimize the adaptive control system.

Fig. 4 presents the block diagram of a production control system where the human decision element was replaced by a dynamic model which ensures the detecting of the error, its analysis and processing in order to modify the structure of the files used by the programming modulus. In this way, we can achieve:

— the control of the available capacities and their automatic convering,

— the optimization of the labour.

The feedback loop is made up of a model which simulates the real production system. The output of this model, representing the desired output is compared to the actual output and, the error is processed with another model in order to change the programming parameters.

The advantage of using a dynamic model consists in the possibility of computing the variables for a succession of subsequent moments which should allow the reprogramming of production under realistic conditions. Thus, if the variables entering the control model at the moment K are measured, by solving the dynamic model, the values necessary for reprogramming at moments $K+1$; $K+2$; ...; $K+n$ can be obtained, a fact which allows the increase of the reprogramming horizon.

The model is conceived by setting out from the hypothesis that various orders are distributed to a section or group of sections with the same technological character, a fact which creates the possibility of temporary exchanges of personnel between sections. By controlling the carrying out of orders on sections-thus measuring the quantity of products received- the model estimates the term when, by maintaining the present conditions (personnel, productivity, production rate), the actual order will be completed that is, at the same time, the real term at which the next order can be launched. By computing the necessities of supplementary personnel (at the sections lagging behind) or the available personnel (at the sections which are ahead of term), the system will redistribute manpower between sections until the equilibration of the production rates in relation to the planned terms for the completion of the orders.

3. Model-reference structure

In recent years it has become possible to formulate dynamic models for industrial behavior with sufficient reality [2].

The central core of industrial systems is the process of manufacturing. One of the first steps in exploring the dynamic behaviour of manufacturing situation is to form a preliminary opinion of what factors are significant. Those factors which affect the delivery must be included. Among these would be level of inventories, the production rate and factors that affect it and the production delay.

Successful selection of factors to include in a system model usually implies a preliminary anticipation of the types of system behaviour that could be important. In the following we shall consider two different approaches.

3.1. *Stock Production System* [3]

Let be a production system where some orders are filled from inventory and some are made specifically to customer order. The state of inventories determines the fraction of orders that can be filled from stock. Manufacturing to customer's special order would need to be included as well as manufacturing to rebuild inventory (Fig. 5).

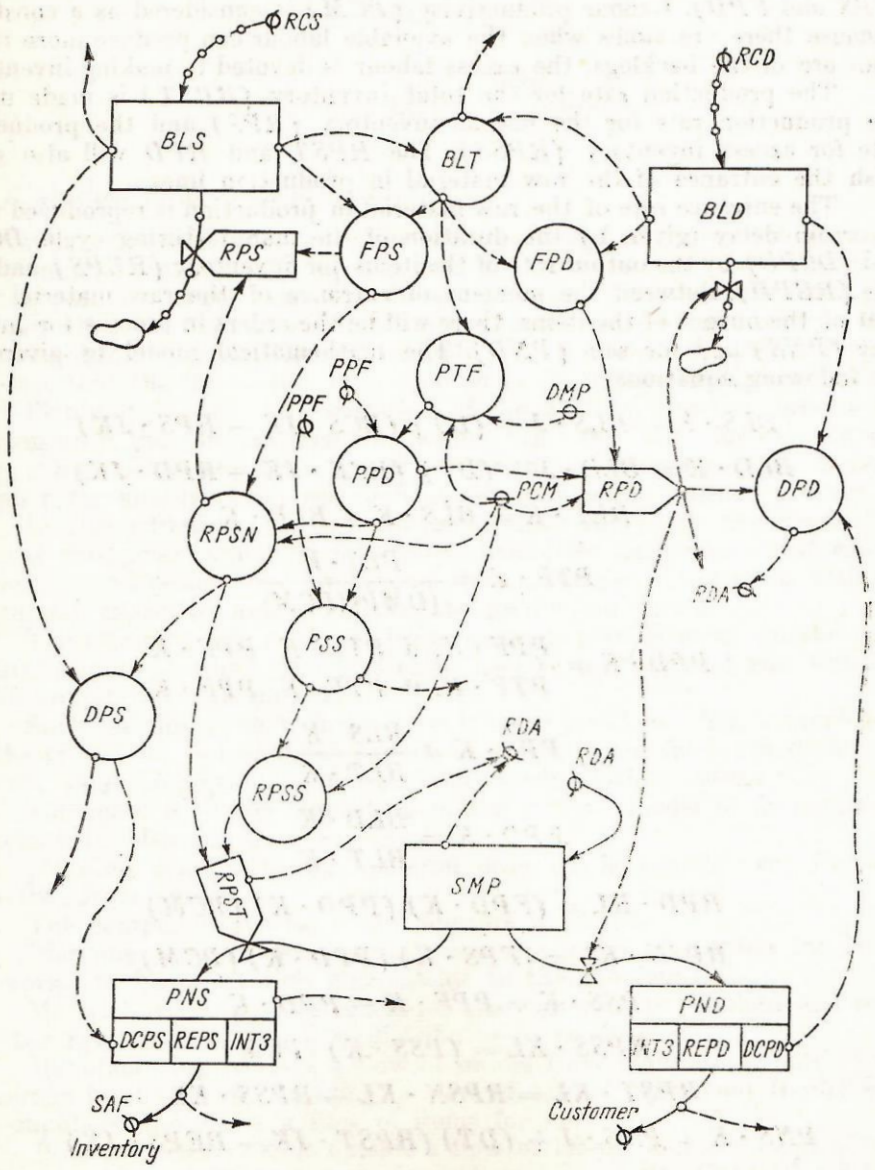

Fig. 5

The production rate for inventory *(RPS)* and the production rate for sales *(RPD)* tend to exhaust the backlog of orders that are to be manufactured for inventory *(BLS)*, respectively the backlog of orders for goods being manufactured for sale *(BLD)*. On the other land, these levels are maintained by the orders rate for inventory *(RCS)* and by the orders rate for sale *(RCD)*. The relation between each backlog and the total backlog designated the fractions of labour to be allocated to each type of production *(FPS and FPD)*. Labour productivity *(PCM)* is considered as a constant. Because there are times when the available labour can produce more items than are in the backlogs, the excess labour is devoted to making inventory.

The production rate for the total inventory *(RPST)* is made up of the production rate for the normal inventory *(RPS)* and the production rate for excess inventory *(RPSS)*. The *RPST* and *RPD* will also establish the entrance of the raw material in production lines.

The entrance rate of the raw material in production is reproduced with a certain delay (given by the duration of the manufacturing cycle *DCPS* and *(DCPD)* by the output rate of the items for inventory *(REPS)* and for sale *(REPD)*. Between the moment of entrance of the raw material and that of the output of the items, there will be the orders in process for inventory *(PNS)* and for sale *(PND)*. The mathematical model ig given by the following equations

$$BLS \cdot K = BLS \cdot J + (DT)\ (RCS \cdot JK - RPS \cdot JK)$$

$$BLD \cdot K = BLD \cdot J + (DT)\ (RCK \cdot JK - RPD \cdot JK)$$

$$BLT \cdot K = BLS \cdot K + BLD \cdot K$$

$$PTF \cdot K = \frac{BLT \cdot K}{(DMP)\,(PCM)}$$

$$PPD \cdot K = \begin{matrix} PPF \cdot K, \text{ if } PTF \cdot K \quad PPF \cdot K \\ PTF \cdot K, \text{ if } PTF \cdot K \quad PPF \cdot K \end{matrix}$$

$$FPS \cdot K = \frac{BLS \cdot K}{BLT \cdot K}$$

$$FPD \cdot K = \frac{BLD \cdot K}{BLT \cdot K}$$

$$RPD \cdot KL = (FPD \cdot K)\ (PPD \cdot K)\ (PCM)$$

$$RPSN \cdot KL = (FPS \cdot K)\ (PPD \cdot K)\ (PCM)$$

$$PSS \cdot K = PPF \cdot K - PPD \cdot K$$

$$RPSS \cdot KL = (PSS \cdot K)\ (PCM)$$

$$RPST \cdot KL = RPSN \cdot KL + RPSS \cdot KL$$

$$PNS \cdot K = PNS \cdot J + (DT)\ (RPST \cdot JK - REPS \cdot JK)$$

$$REPS \cdot KL = INT3(RPST \cdot JK \cdot DCPS)$$

$$PND \cdot K = PND \cdot J + (DT)\,(RPD \cdot JK - REPD \cdot JK)$$

$$REPD \cdot KL = INT3(RPD \cdot JK,\ DCPD)$$

$$SMP \cdot K = SMP \cdot I + (DT)\,(RDA \cdot JK - RPST \cdot JK - RPD \cdot JK)$$

$$DPS \cdot K = DCPS + \frac{BLS \cdot K}{RPSN \cdot K}$$

$$DPD \cdot K = DCPD + \frac{BLD \cdot K}{RPD \cdot K}$$

3.2 *Production system with planning*[4]

When, the activity in an industrial enterprise starts from the principle of planning, the model will have to take into account the fact that the inventory will no longer exist or will be minimum. Working only for a production which has the sale ensured the models will have to take into account the correlation of production with supply (which is also planned) as well as the fact that the fluctuation of manpower is practically negligeable.)

Planning implies the correlation of the whole production process beginning with the raw material and ending with the items for sale. In this way, a logical concatenation appears, a producer becoming a raw material supplier for another producer, and so on, up to the finished product.

In this situation, the raw material which represents the product of another enterprise cannot be obtained in boundlees quantities and it cannot remain unused either. The production plan correlates all resources with the production capacities and establishes the production volume.

The effective fulfilment of the production plan is made on the basis of firm contracts which should finally lead to the physical and financial fulfilment of the plan indices.

Such an enterprise is facing a particular problem when a great part of the production is meant for export, especially when the fabrication cycle is very short (for example, in the ready-made clothes industry).

The main activities appearing in the general model of an industrial system with planning are:

planning, manufacturing, material ordering, labour, delivery, financial activity, development.

The completed general model appears in Fig. 5.

Planning receives orders from customers and issues orders inside the enterprise to manufacturing and outside to the suppliers.

Material ordering issues orders for raw materials to suppliers and receives the raw material which it distributes to production.

Manufacturing receives a flow of orders from planning, a flow of raw materials from material ordering, a flow of capital equipment (tools) from the suppliers and sends a flow of items for sale.

Personnel receives from outside a flow of labour and communicates by information flows with manufacturing, planning and the financial activity.

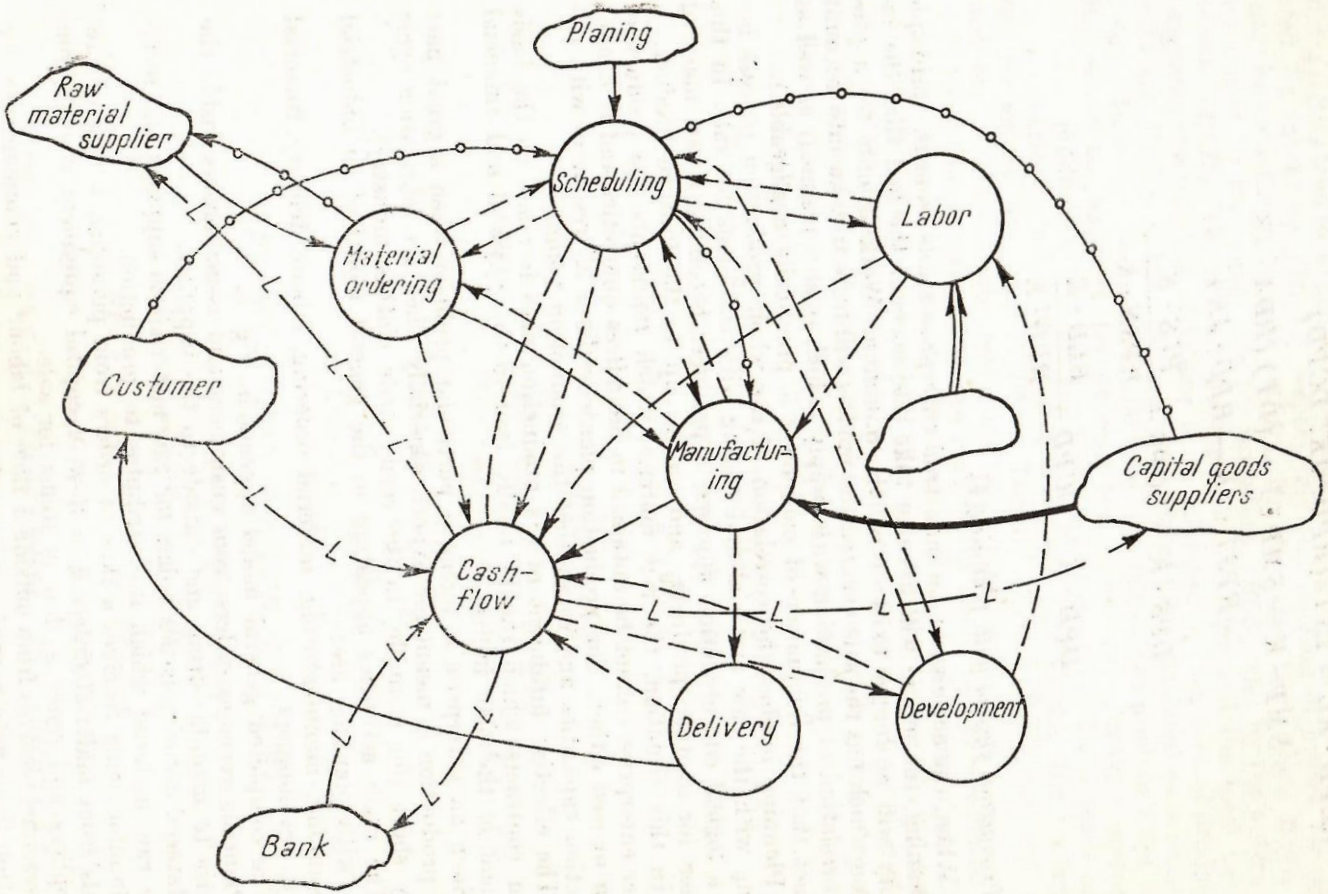
Planing
Raw material supplier
Scheduling
Labor
Material ordering
Custumer
Manufacturing
Capital goods suppliers
Cash-flow
Delivery
Development
Bank

Fig. 6

The sales department receives items from production and delivers them to the customers, communicating information to the planning and financial activity.

The financial activity concentrates the cash flow linking the enterprise with the exterior and receives information from all the other functions of the enterprise.

Development is providing planning with data on the production capacities which will result through the assimiation of new tools, technologies and products, conveys to the personnel activity data on the volume of the personnel which has to be trained for the new capacities and provides the financial function with data on the necessary money implied by the increase of the production capacities and of the personnel. It receives data on the necessary new production capacities from planning and on the financial resoruces for development.

The production flow related to the inventory completion no longer appears in this model. In exchange, the division of production into: production for export and production for the home market is taken into account. This distinction is necessary because the planning, material ordering and delivery activities are organized on two following different roads: one for goods that go to export and the other for goods made for home market. In actual practice, the manufacturing operation is intermixed in the same production lines, but in the model these two flows are treated separately to provide to necessary variables representing each of the two flows. Consequently, Fig. 7 shows two backlogs of orders and two production delays. There is no priority given to either category in this formulation.

The orders rate for export, respectively for the home market is added to the backlog, denoted by *BLE* and *BLI*. The output from these levels is made by carrying out the orders, which is controlled by the production rate for export *(RPE)* and for the home market *(RPI)*. The productive personnel is allocated to the two types of production in fractions proportional to *BLE* and *BLI* (*FPE* and *FPI*). Under these conditions, the production rate is equal to the product between the personnel fraction affected to a type of production and the total personnel *(PACTV)* multiplied by the effective physical productivity of labour (*PEME* and *PEMI*). The effective physical productivities are computed from calculated productivities *(PCME, PCMI)* and the variations of registered productivity *(VPME, VPMI)*.

The production rates also control the entrance of the raw material from the raw material stocks (SAMPEE, SAMPFI) into the productive sections. Between the entrance of the raw material into the section and its issue in the form of finished items there is a time interval which is the length of the manufacturing cycle *(DCPE* and *DCPI)*.

In this way, the manufactured rates *(REPE* and *REPI)* reproduce with a delay equal to *DCPE*, respectively *DCPI*, the entrance rate of the raw material into the section. During this interval, we have in the section an unfinished production *(PNE, PNI)*.

The planned duration of the exhaustion of the backlog by carrying it out is *DBL*. The effective durations of the carrying out of the orders com-

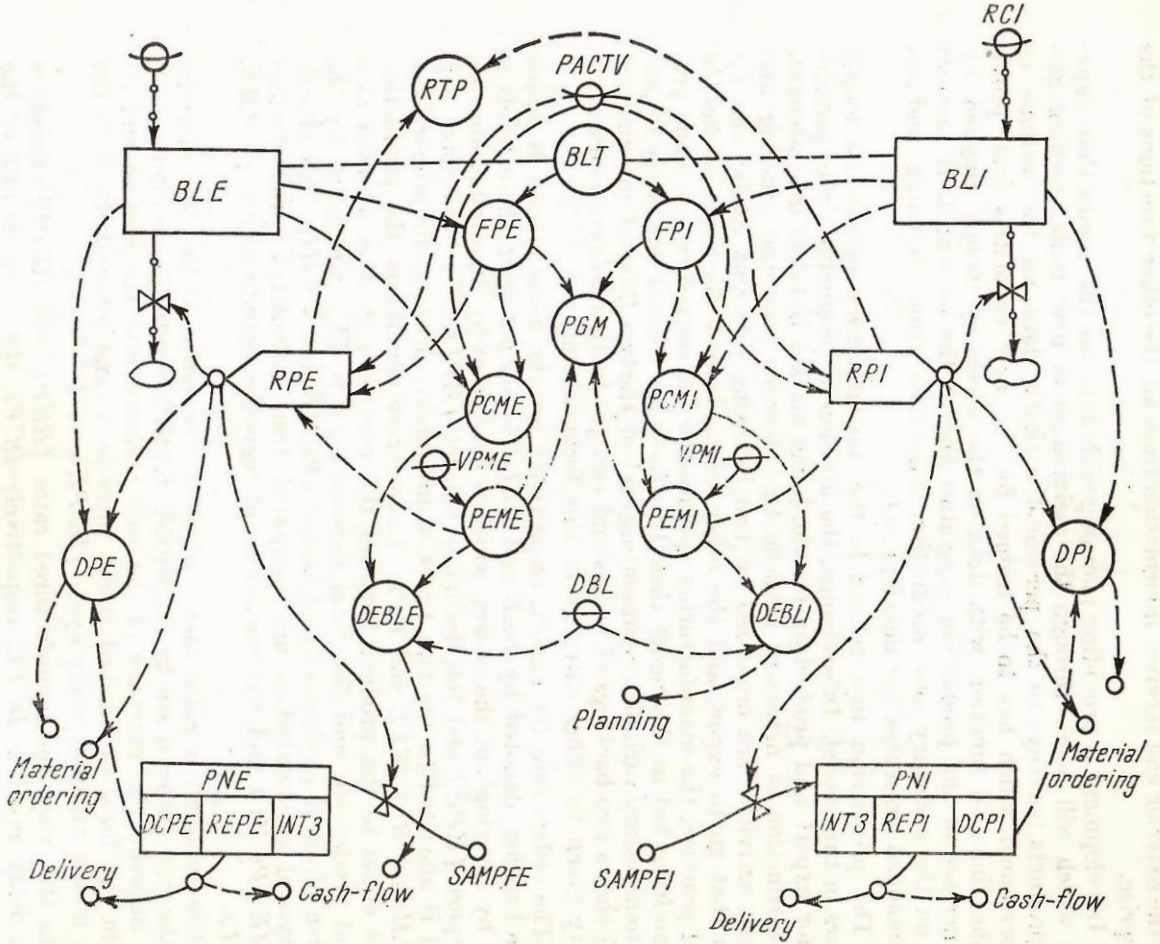
RCI
RTP
PACTV
BLT
BLE
BLI
FPE
FPI
PGM
RPE
RPI
PCME
PCMI
VPME
VPMI
PEME
PEMI
DPE
DPI
DBL
DEBLE
DEBLI
Planning
Material ordering
PNE
DCPE
REPE
INT3
Delivery
Cash-flow
SAMPFE
SAMPFI
PNI
INT3
REPI
DCPI
Material ordering
Delivery
Cash-flow

Fig. 7

prised in *BLE* and *BLI* are noted by *DEBLE* and *DEBLI*. They are calculated as a product between *DBL* and the calculated productivity.

The mathematical model is given by the following set of equations:

$$BLE \cdot K = BLE \cdot J + (DT)(RCE \cdot JK - RPE \cdot JK)$$

$$BLE = BLE$$

$$BLI \cdot K = BLI \cdot J + (DT)(RCI \cdot JK - RPI \cdot JK)$$

$$BLI = BLI$$

$$BLT \cdot K = BLE \cdot K + BLI \cdot K$$

$$FPE \cdot K = \frac{BLE \cdot K}{BLT \cdot K}$$

$$EPI \cdot K = \frac{BLI \cdot K}{BLT \cdot K}$$

$$PCME \cdot K = \frac{BLE \cdot K}{(PACTV \cdot K)(FPE \cdot K)(DBL)}$$

$$PCMI \cdot K = \frac{BLI \cdot K}{(PACTV \cdot K)(FPI \cdot K)(DBL)}$$

$$PEME \cdot K = PCME \cdot K + VPME \cdot K$$

$$PEMI \cdot K = PCMI \cdot K + VPMI \cdot K$$

$$PGM \cdot K = (FPE \cdot K)(PEME \cdot K) + (FPI \cdot K)(PEMI \cdot K)$$

$$RPE \cdot KL = (PACTV \cdot K)(FPE \cdot K)(PEME \cdot K)$$

$$RPI \cdot KL = (PACTV \cdot K)(FPI \cdot K)(PEMI \cdot K)$$

$$DEBLE \cdot K = \frac{PCME \cdot K}{PEME \cdot K} \cdot (DBL)$$

$$DEBLI \cdot K = \frac{PCMI \cdot K}{PEMI \cdot K} \cdot (DBL)$$

$$RTP \cdot KL = RPE \cdot KL + RPI \cdot KL$$

$$PNE \cdot K = PNE \cdot J + (DT)(RPE \cdot JK - REPE \cdot JK)$$

$$PNE = (DCPE)(RPE)$$

$$REPE \cdot KL = INT3(RPE \cdot JK, DCPE)$$

$$PNI \cdot K = PNI \cdot J + (DT)(RPI \cdot JK - REPI \cdot JK)$$

$$PNI \cdot K = (DCPI)(RPI)$$

$$REPI \cdot KL = INT3(RPI \cdot JK, DCPI)$$

$$DPE \cdot K = DCPE + \frac{BLE \cdot K}{RPE \cdot JK}$$

$$DPI \cdot K = DCPI + \frac{BLI \cdot K}{RPI \cdot JK}$$

4. Comparator and adaptor structure

The comparator generates the error signal between the actual and desired response, and the adaptor processes this error and indicates the decision which has to be taken in relation to the nature of error Fig. 8 [5].

The production rate RP is calculated as a product between the number of employees in the section, PS and the labour productivity at the product which is being carried out, *PMP*. Considering as calculus data the quantity of products received, *CR*, the quantity of products launched, *CL* and *RP*, the time until the finishing of the order, TTC results, to which is added the delay of the unfinished production, *PN* in the section. Knowing the standardized length of production, *DNP* and the time which elapsed since launching, *T*, the planned time until the finishing of the order, *TPTC* results. The difference between *TTC* and *TPTC* represents the production, delay, *IP*, which may be positive proper delay or negative (outrunning of the plan). In both cases, multiplying *IP* by *RP*, the quantity of the envisaged remaining products *PRP* is resulting which divided by *TPTC* is leading to the value of *RSNP*, the necessary supplementary production rate. The ratio between *RSNP* and *PMP* is the personnel error, *ERP* which, if positive, has the significance of an additional personnel necessary in the section, *PNES* and, if negative, the significance of an available personnel in the section.

The summation of the positive values *ERP* for all sections with the same character is leading to the value of the necessary personnel *PNE* and, the summation of the negative values *ERP* for all sections gives the total available personnel, *PD*. Appearing at this moment is all information necessary for the decisions on the reallocation of the personnel in sections according to the stages of the fulfilment of the plan. The ratio between *PNE* and *PD* gives the fraction of the allocable personnel, *FPA*. This fraction multiplied by *PNES* gives the personnel temporarily allocated to the respective section, *PAT*. The personnel allocation rate, *RAFP* is given by the value *PAT* and the allocation time, *TA*. Similarly, if the section has an available personnel *PDS* which is to be affected to other sections, the disaffected personnel in the section, *PDA* is *PDS* with changed sign. The disaffectation rate *RDAP* is calculated the same as *RAFP*.

The difference between *PNE* and *PD* at the level of the group of sections with the same technological character represents the total personnel error, *ETP*. If positive, it represents an information which substantiates the decision on the employment of personnel, *PA*, because the reallocation has equilibrated the production rate and the delays, but, could not cancel these delays. If *ETP* is negative, it means that unsued production capacities have appeared, or, what is equivalent, an additional realizable production,

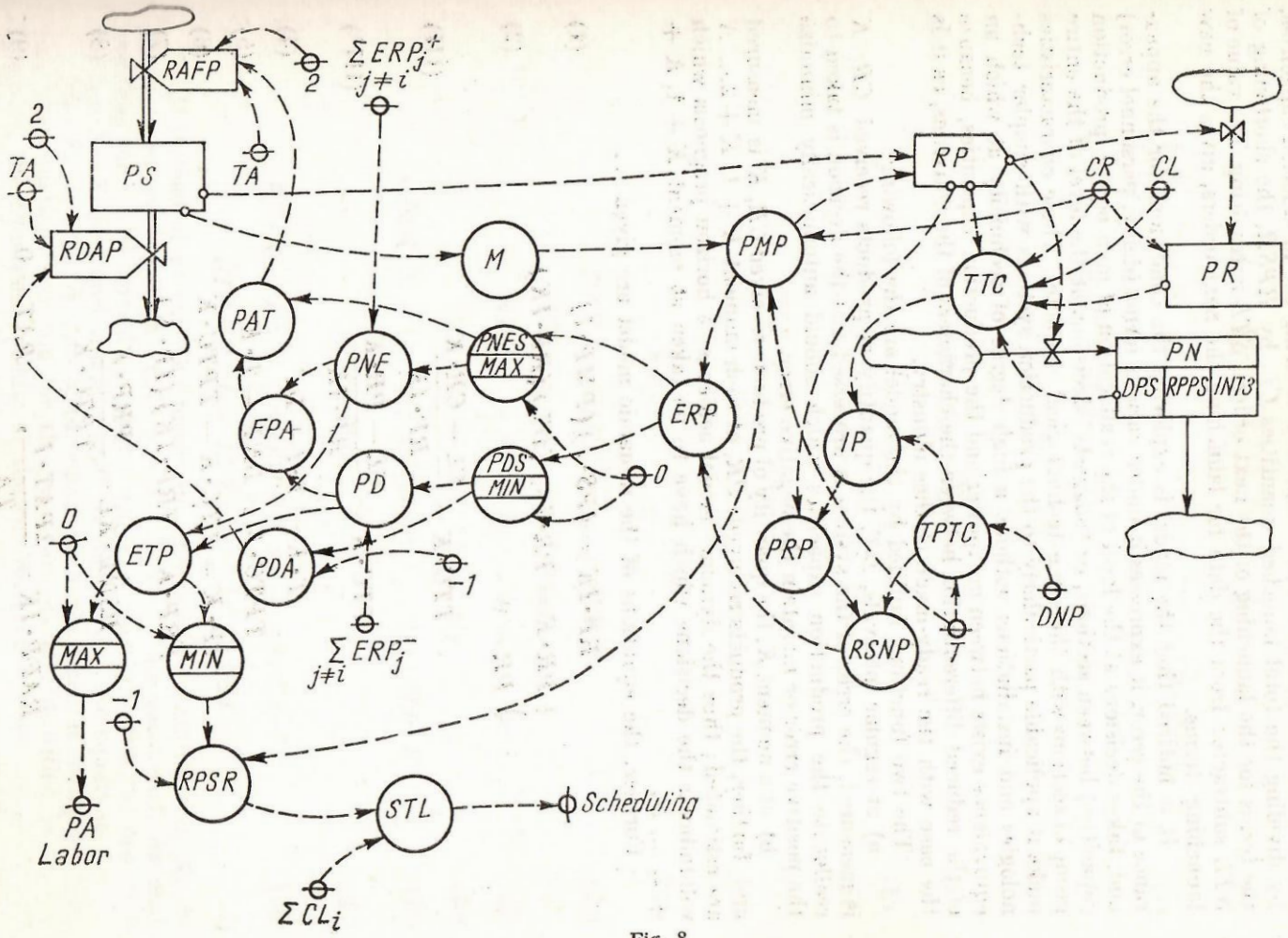
RAFP
2
$\sum_{j\neq i} ERP_j^+$
2
TA
PS
TA
RDAP
M
PMP
RP
CR
CL
PR
TTC
PAT
PNE
PNES
MAX
PN
DPS
RPPS
INT3
FPA
ERP
IP
PDS
MIN
0
PD
0
ETP
PDA
-1
PRP
TPTC
DNP
MAX
MIN
$\sum_{j\neq i} ERP_j^-$
RSNP
T
-1
RPSR
STL
Scheduling
PA
Labor
$\sum CL_i$

Fig. 8

rate $RPSR$ has appeared. For completely covering the production capacities, by dividing the total launched quantities CL_i by $RPSR$, the shortening of the terms for the launching of the next orders, STL is resulting. The value of STL subtracted from the data for launching the next orders, gives the new launching terms.

It is noticed that the model is exploring the conditions for the appearance of the error, it expresses it under various forms (delay, personnel error) and, takes decisions at the level of the reallocation of man power (production capacities) between sections, or "suggests" decisions at the level of the entire group of sections with the same technological character. These characteristics make it applicable particularly to the production systems with simpler technologies and installations without a high degree of technicity at which an equivalence exists between manpower and the production capacities, because of the reduced differentiation between the characters of the activities, as it is the case with the ready-made clothes industry.

The two functions fulfilled by the model are the following:

a) at regular intervals, DT, the quantity of products received CR, K is measured, the error of the system is processed and the decision is taken to reallocate the production capacities which should automatically minimize the positive error or maintain the negative error.

b) at a moment K, the quantity of products received CR, K is measured and, further, the products received, PR, at each moment $K+1$, $K+2$, ... N are estimated; thus the dynamic model achieves a horizon prognosis which will indicate the decisions which have to be taken at moment $K+1$, $K+2$, ..., N.

Further, the equations of the dynamic model are given ...

$$RP \cdot IK = (PS \cdot I)(PMP \cdot I) \tag{1}$$

$$\begin{cases} PR \cdot K = PR \cdot I + (DT)(RP \cdot IK) \\ PR = 0 \end{cases} \tag{2}$$

$$TTC \cdot K = \frac{CL - CR \cdot K}{RP \cdot IK} \tag{III}$$

$$TTC \cdot K = \frac{CL - PR \cdot K}{RP \cdot IK} \tag{III*}$$

$$T \cdot K = T \cdot I + DT \tag{4}$$

$$TPTC \cdot K = DNP - T \cdot K \tag{5}$$

$$IP \cdot K = TTC \cdot K - TPTC \cdot K \tag{6}$$

$$PRP \cdot K = (RP \cdot IK)(IP \cdot K) \tag{7}$$

$$RSNP \cdot KL = \frac{PRP \cdot K}{TPTC \cdot K} \tag{8}$$

$$RAFP \cdot IK = \frac{2PAT \cdot I}{TA}, \qquad PAT = 0 \tag{9}$$

$$RDAP \cdot IK = \frac{2PDA \cdot I}{TA}, \qquad PAT = 0 \tag{10}$$

$$\begin{cases} PS \cdot K = PS \cdot I + (DT)\,(RAFP \cdot IK - RDAP \cdot IK) \\ PS = PSO \end{cases} \tag{11}$$

$$M \cdot K = M \cdot I + PS \cdot K, \qquad M = 0 \tag{12}$$

$$PMP \cdot K = \frac{CR \cdot K}{M \cdot K} \tag{XIII*}$$

$$ERP \cdot K = \frac{RSNP \cdot KL}{PMP \cdot K} \tag{14}$$

$$PNES \cdot K = MAX(ERP \cdot K,\ O) \tag{15}$$

$$PNE \cdot K = PNES \cdot K_i + \sum_{j \neq i} PNES \cdot K_j \tag{16}$$

$$PDS \cdot K = MIN(ERP \cdot K,\ O) \tag{17}$$

$$PD \cdot K = PDS \cdot K_i + \sum_{j \neq i} PDS \cdot K_j \tag{18}$$

$$FPA \cdot K = \frac{PNE \cdot K}{PD \cdot K} \tag{19}$$

$$PAT \cdot K = (FPA \cdot K)\,(PNES \cdot K) \tag{20}$$

$$PDA \cdot K = (-1)\,(PDS \cdot K) \tag{21}$$

$$ETP \cdot K = PNE \cdot K - PD \cdot K \tag{22}$$

$$PA \cdot K = MAX(ETP \cdot K,\ O) \tag{23}$$

$$RPSR \cdot K = (-1)[MIN(ETP \cdot K,\ O)]\,(PMP \cdot K) \tag{24}$$

$$STL \cdot K = \frac{\Sigma\, CL_i}{RPSR \cdot K} \tag{25}$$

$$PN \cdot K = PN \cdot I + (DT)\,(RP \cdot JK - RIPES \cdot JK) \tag{26}$$

$$RIPFS \cdot KL = INT3(RP \cdot JK,\ DPS) \tag{27}$$

If instead of periodically measuring the received quantity CR, K, the products received $PR \cdot K$, $PR \cdot K + 1$, ... $PR \cdot N$ are estimated, we shall say that the model carried out at moment K a prognosis with the prognosis horizon $N-K$. Obviously, in this case, by replacing in the equations $CR \cdot K$ by $PR \cdot K$, ..., $PR \cdot N$, part of the equations of the model is changed. Therefore the equations common for the two variants are identified by Arabic numbers, the equations specific of the control type variant are indentified by Roman numbers and the equations specific of the prognosis type variant are marked with an asterisk.

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PROJET DE SYSTÈMES POUR LE CONTRÔLE DE LA PRODUCTION

Les progrès de la théorie moderne du réglage automatique et de la technique de calcul permettent un traitement extensif des aspects non liés aux procédés des sytèmes de l'informatique.

Pour réaliser un système perfectionné de gestion opérationnelle de la production on peut utiliser des techniques spécifiques à la cybernétique. On propose une solution pour que le système opérationnel de gestion de la production soit un système adaptable à un modèle étalon (dynamique).

ПРОЕКТ СИСТЕМ ДЛЯ КОНТРОЛЯ ПРОИЗВОДСТВА

Прогресс современной теории автоматического регулирования и техники расчета делает возможным экстенсивное рассмотрение непроцедурных аспектов информатических систем.

Для осуществления усовершенствованной системы оперативного руководства производством можно использовать специфическую для кибернетики технику. Предлагается решение таким образом, чтобы система оперативного руководства производством была адаптивной системой с моделью-эталоном (динамической).

8.X.1973