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Production Scheduling in Industrial Enterprises

"Scheduling is a field in which there are some intriguing problems and some interesting answers."

Richard W. Conway
William L. Maxwell
Louis W. Miller

Production scheduling is one of the most complex and topical problems of economic practice at enterprise level, about which it can be said that it is still far from having been solved scientifically and efficiently even in the industrially developed countries, with a tradition in this domain.

One of the most typical characteristics of this complex problem is in our opinion, the existence of a multitude of meanings given to it and which are circulating in parallel, as a result of its large number of aspects which theoreticians or practicians often consider to be separated from the context, in keeping with the special situation with which they are faced.

The present study is trying to review the main problems-aspects of the production efficient scheduling to show how they are connected between them and to outline some ideas about the possibilities for a theoretical and practical solution.

The problems of the production efficient scheduling we shall dwell on in continuation are the following (4):

— the optimization of the range structure of the medium and short-term plan;

— the establishment of the outfit of raw and related materials corresponding to a well determined plan;

— some of the technological aspects of efficient scheduling;

— the launching, control and updating of production;

— some ergonomic aspects in production planning.

— some psycho-sociological problems of efficient scheduling.

Let us examine in brief the characteristics of each of them.

The optimization of the range structure of the medium-term plan (a year, half year, quarter) and short-term plan (a month, ten days, a week, a day, an hour) is the operation on the border between planning and operative programming. Through the medium-term plan, the quantities which have to be produced within a quarter are being established, and the range structure can be improved by taking into consideration the global restrictions as regards the available production capacities for very short periods of time (a month, ten days, a day) without detailing the assortments on subensembles, components and operations and the hypothesis of the rhytmicity of production being accepted as a rule. The passing from this spacing out, which is useful for giving global data on the future unfolding of production to the spacing out in which the detailed aspects of production, especially those concerning the utilization in time of the human and material resources start and are taken into consideration, represents, in fact, the passing from the level of planning to the level of production scheduling proper. As the assortment structure of the medium-term plan represents *an input data* in the operation of production scheduling (on a short-term), people specialized in the latter are interested in taking part in working out the medium-term assortment plan and in finding scientific methods, at the same time operational for this problem.

A problem which is often associated by practicians with production scheduling is the *establishment of the necessary resources for carrying out a pre-established plan*, especially of the outfit of raw and related materials. This problem is closely linked with the resources supply which, in its turn, conditions the possibilities of achieving the products and the assortments according to the plan. The other side of this problem is the establishment of the quantities of certain assortments which can be produced with the quantities of resources existing at a given moment. Of course, the two problems regard, in the first place, specialists in technology and supply, but, their strong influence on the effective fulfilment of the plan justifies their inclusion into the sphere of the preoccupations concerning production scheduling.

There are many *technological aspects* in the production scheduling. Thus, besides the afore-mentioned problem of the establishment of the necessary resources, whose technological aspect consists in establishing the structure of a product (the inclusion into subunits and components) and the specific consumptions, one of the technological problems with profound implications in production scheduling is the designing of the succession of operations leading to the obtaining of the desired products or, in other words *the projection of fabrication technologies*. According to a number of main characteristics, specialists classify the fabrication processes into several big classes (the production of single pieces, small, medium or big mass production, with a group technology, the organization of on the line production, etc.), the belonging of a certain productive process to one of these classes having a decisive influence on the production scheduling methods which have to be used.

The launching, control and updating of production is, undoubtedly, the main problem of production scheduling. The point in question is *the establishment in detail* of the units or unit lots which are to be carried out in the considered short period and the fixing of *the moments* when each unit or lot is started or

finished, in fact, *the spacing out in time of the operations made on the units or lots by specifying the distribution of the resources* (*machines*, *materials*, *labour*) *on these operations in time.*

This complex process of production organization is called in the Anglo-Saxon literature of especiality *scheduling* and in the French one- *ordonancement.*

To have an efficient methodology of production launching, control and updating is, of course, equal to solve the problem of production scheduling however, experience shows that the attempt to separate this problem from the context, that is to separate it from the other above-mentioned aspects, leads to approaches most often practically inapplicable (2).

The ergonomic and psycho-sociological aspects, usually considered as distinct from those of production scheduling, should in our opinion be included within the preoccupations concerning production scheduling, because no matter how improved its methods are, its human aspects cannot be ignored, in the last analysis being decisive as regards the final success.

Considering the above-mentioned aspects, one can distinguish two large directions of approaching the problem of production scheduling.

1. the general approach, aiming at including and solving the problem in its entire complexity;

2. the pragmatic approach, aiming to find efficiently applicable solutions, sometimes sacrifying the aspects of generality and scientific strictness.

The general approach to the problem of production scheduling pertains to theoretical research at present. By excluding the very simple types of problems for which complete solutions exist, the theoretical solution in general and the practical one, in particular, to the problems of big and even medium-sized complexity, naturally, belongs to the future. This is due both to the difficulty of finding models which should satisfactorily reflect the complex problem of production scheduling and especially to the impossibility of solving these models at present, even with the aid of the most powerful electronic computers.

In the light of the progress to be scored in the future in this respect, we shall outline, in the following, some of the ideas about *the systemic consideration of the problem of production scheduling.* Thus, we shall consider a system whose main objective is the fulfilment of production in the given conditions. This system will be called *the system of production scheduling* (the POP system). It is difficult to conceive a complete definition of this system. In exchange, a number of characteristics of the system can be defined, namely: the components, the variables and parameters, the conditions, activities, events, data, restrictions, objectives, variants, decisions, the updating methods, accessibility, controlability, adaptability and stability of the system. The specification of these characteristics of the POP system helps in understanding its way of functioning.

The components of the POP system are very numerous and varied: workers of various professions and specialities, raw and related materials, the products of work in various stages of fulfilment, fuel, energy, lubricators, devices, equipment, installations, storing rooms, etc. The data can also be considered as components of the system, but, they will be dwelt on separately,

because they present some particularities. Obviously, man is playing the main part within the POP system.

The main component part within the POP system on which man acts directly or indirectly, through the tools, devices or equipment, is the product of labour in various stages of processing. In current terminology, this component is called unit.

The variables of the POP system can be classified into: endogenous, exogenous and perturbative.

The endogenous variables X_i (input variables) can be: the volume of the demands for products (on assortment), the terms required for certain demands, the rate of supply with raw and related materials, quality indices, etc.

The exogenous variables X_e (output variables) can be: effectively achieved quantities, delivery terms, the effectively achieved quality, etc.

The perturbative variables X_p can be: demands for supplementary volumes for certain products which are being carried out, discrepancies in the planned terms of supply with raw and related materials, in the terms when they were received, supplementary periods for the maintenance and repair of equipment, the number of workers absent from their places of work, etc.

The state of the POP *system* at a given moment t is characterized with the aid of a state vector $S(t)$ whose elements are the parameters of state of the main components, namely:

$$S(t) = [\lambda_1(t), \lambda_2(t) \ldots \lambda_p(t)]$$

The set of all possible states (Σ) represents the space of the state.

The activities within the POP *system* consist of changes in the condition of the components, the main aim being the change in the condition of the units in keeping with a technological process and which must be most rational.

Some activities consists in direct changes in the units, such as for example: processing activities (changes of structure, form, composition, of the units), assembling activities, transport activities (change in the space coordinates of the components). Another group of activities consist in indirect changes in the units, such as for example: servicing units (changes in other components for facilitating the processing of units); activities for the transport of some components (various units).

For each pair of activities (A_i, A_j) a relation of succession in time (of precedence or indifference) should be defined. A *succession* of activities is the set of activities between which a series of succession relations was defined.

The *events* mark the change in the state vector of the components, the beginning or end of activities.

The events mark the beginning or end of some groups of activities or of extremely important activities which are called *key events.*

The events generating activities undesired in the system are called *perturbative events.*

The data within the POP system ensure the knowing of the variables and of the state parameters with a view to carrying out the processing of the units in keeping with the planned technological process and the delivery in term of the products.

The constraints *of the* POP *system* are, generally, of a limitative type (the non-surpassing of some of the admissible limits of the state parameters,

the non-surpassing of some limits imposed on some variables, such as is the case of the delivery terms, etc.). Other types of constraints express certain relations between the variables and parameters characterizing the components of the system. For example, a certain semi-product is achieved by using a given proportion between the materials of which it is made up.

The objectives of the POP *system* can be functional and economic. The functional objectives consist in ensuring the transformation of the units so that, by setting out from the initial condition $S_I(t_I)$, at a given moment $t_\alpha \geqslant t_I$ the final condition $S_F(t_F)$ at a moment $t_\omega \leqslant t_F$ *be reached.* The economic objectives consist in satisfying the various optimum criteria of the system (the minimization of costs or consumptions of resources, the maximization of profits, the minimization of the length of expectation of the units or equipment, etc.).

The variants within the POP system consist of various successions of activities possible from the technological and organizational points of view (compatible with the constraint of the system) to which are attached some components at various moments, so as to achieve the functional objectives.

The decision in the POP system consists in choosing those successions of activities which constitute variants and then in establishing the variant which rigorously satisfies the economic objectives of the system (the optimum variant) or at least approaches them conveniently (the suboptimum variant). The centralized decisions comprise a certain number of sections, workshops, groups of installations, etc. and consist in establishing incompletely defined variants but which specify a series of key events, some fused activities to which are attached various global groups of components. The local decisions specify the variants in detail going up to the place of work, by establishing each activity and the afferent components, so as to observe the conditions imposed by the centralized decision. It is obvious that the centralized decisions refer to bigger periods of time (decades, months) and the local decisions to shorter periods (weeks, days and even hours).

The updating methods constitute variants for the fulfilment of the objectives of the POP system in case that perturbative events have appeared. The permanent control of the POP system is ensured through the updating of data on the state variables and parameters. If, as following the updating of data, it is noticed that the state of the system at the moment t_a is $S^*(t_a) \neq S(t_a)$ where $S(t_a)$ represents the state vector of the system for the moment t_a, supposing the absence of the perturbation, and if: $(F)i, |\lambda^*(t_a) - \lambda_i(t_a)| \geqslant \Delta\lambda_i (\Delta\lambda_i$ the admissible deviation of the state parameter i), we pass to the updating of the system decisions.

The accessibility of the state S_F at the moment t_F of the state S_o, at the moment t_o, is the property of the system of having at least one variant $V_{t_o}; t_F$ which should bring the system from the state S_o to the state S_F.

The set of theaccessible state of state S_o is noted $\Sigma(S_o)$ and has the property that $\Sigma(S_o) \subseteq \Sigma$.

The controllability of the system from state S_0 with reference to $\Sigma(S_0)$ is the property that each state of $\Sigma(S_0)$ be accessible in S_0. If $\Sigma(S_0) = \Sigma$ the system is entirely controllable.

This cannot happen actually unless the space of the possible final state is limited.

Adaptability is the property of the POP system of carrying out the economic objectives within admissible limits, even in the conditions of the appearance of perturbations. If U_0 is the optimum value of each objective function, for example a utility function, the effective value of U must satisfy the relation:

$$U \geqslant U_0 - \Delta U$$

where ΔU represents an admissible deviations.

Adaptability is ensured by updating the centralized decisions.

Stability is the property of the system of returning to the state trajectory adopted through the initial decision, in the event of a perturbation which appeared suddenly.

Stability is ensured especially by updating the local decisions.

The above considerations represent in fact a general framework with a rather terminological character which might allow to tackle the production scheduling from a systemic point of view. Obviously, the blending of notions into a logical-mathematical whole which should reflect the process of production scheduling is a question of the future.

As regards the possibilities of the pragmatic approach to the problem, they are large and diverse. If we refer to the very complex cases of production scheduling that is to the problems of a large series type, with hundreds or thousands of units, hundreds or thousands of necessary resources (raw and related materials, machines, workers, etc.) and eventually, with the utilization of the same machines for processing several units, the main idea allowing a pragmatic approach is that of an intelligent combination between the centralized and decentralized decisions. This means, in the first place, that simplified global models should be found, models capable of allowing their treatment on the computer and which, at the same time, should reflect the main point of the phenomenon. They would represent the work instrument at the level of the "control table" and would allow updating interventions whenever the condition of the system requires it.

Secondly, it is necessary to find basic practical rules at the level of those in charge, in detail, of production scheduling. The decentralization of the decisions of production scheduling can be made up to the level of the foremen and team leaders; however, it is essential that decentralization should not mean to leave the problem exclusively on the account of the "experience" and "talent" of the decision-makers at this level, but, if possible, to arm them with precise decision rules for the most typical and frequent cases of deviation from the scheduled parameters.

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A large team of researchers in the operations research sector of our department laboratories are working, on a contract basis, on solving problems of production scheduling in industrial enterprises. In collaboration with the specialists of the respective enterprises, the above-mentioned ideas and prospects are pursued, the first practical experiments going to start during the next few months. Due to the ampleness and importance of the problem approached, these very lines constitute an invitation to a large exchange

of opinions of specialists with an experience in this domain, using among other things the columns of our review and any other form communication which might contribute to the progress of solving the problem.

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LA PROGRAMMATION OPERATIONNELLE DE LA PRODUCTION DANS LES ENTREPRISES INDUSTRIELLES

On énonce les principaux problèmes de la programmation opérationnelle de la production et on ébauche certaines idées concernant les possibilités de leur résolution théorique et pratique. En considérant qu'il existe deux manières d'aborder le problème, notamment l'une générale et l'autre pragmatique, les auteurs se proposent de présenter — se situant dans la perspective du premier point de vue — toute une série de concepts caractéristiques du système de la programmation opérationnelle de la production. Ils ont défini à cette fin: les composantes, les variables et les paramètres, les états, les activités, les événements, les restrictions, les objectifs, les variantes, les décisions, les méthodes d'actualisation, d'accessibilité, de controlabilité, d'adaptabilité, de même que la stabilité du système de la programmation opérationnelle de la production.

ОПЕРАТИВНОЕ ПРОГРАММИРОВАНИЕ ПРОИЗВОДСТВА НА ПРОМЫШЛЕННЫХ ПРЕДПРИЯТИЯХ

В настоящей статье излагаются основные проблемы оперативного программирования производства и затрагиваются отдельные вопросы в связи с возможностями их теоретического и практического решения. Считая, что существуют два способа освещения проблемы, а именно один общий и другой прагматический, авторы ставят пред собой задачу представить в статье, исходя из перспективы первой точки зрения, ряд определяющих понятий системы оперативного программирования производства. С этой целью были определены : компоненты, переменные и параметры, состояния, виды деятельности, события, ограничения, цели, варианты, решения, методы актуализации, доступность, контролируемость, приспособляемость и стабильность системы оперативного программирования производства.

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