POSSIBILITIES OF INCREASING EFFICIENCY WITHIN SERIAL PRODUCTION MANAGEMENT

CODRUȚA DURA, CLAUDIA ISAC, IMOLA DRIGĂ *

ABSTRACT: *Under the impact of transition to the new post-industrial society, mass production recently faced the most numerous difficulties. They are caused by turbulences in the external environment in which companies operate, manifested in particular by enhancing the dynamism of markets and by deep changes in the structure of consumers' demands. In this context, specialized literature records the concerns for increasing the efficiency and flexibility of products, elements involving radical changes of management and manufacturing technologies methods. Given these issues, the paper approaches two separate ways to improve the management of serial production: increasing economic efficiency by optimizing the size of batches and flexible production systems by implementing techniques to reduce the change-over time.*

KEY WORDS: *information society; serial production; batch production; the optimal batch size; SMED method; the change-over time; input exchange die; output exchange die*

JEL CLASSIFICATION: *M11, L60*

1. INTRODUCTION

The last decades have been marked by an unprecedented development of information and communication technology (ICT), a rather complex phenomenon that has been felt by all sections of economic and social life. Reported some time ago, *the information age* seems to gradually replace the *industrial era* while the traditional society is replaced by the new *information society*. In the early '90s, the concept of information society was formulated; it means a series of profound and complex economic, social, political and cultural changes affecting the lives of individuals and which were the result of an explosive development of information and communication technologies. Among the positive effects of these changes the most visible are worth

* *Assoc.Prof., Ph.D., University of Petrosani, Romania, codrutadura@yahoo.com*
Assoc.Prof., Ph.D., University of Petrosani, Romania, isacclaudia@gmail.com
Lecturer, Ph.D., University of Petrosani, Romania, imola.driga@gmail.com

mentioning: reducing spatial and temporal constraints on communication accelerate the speed of processing, storing and transmitting of information, lower prices of services related to transferring information etc. In such an environment, economic activities take new forms of expression, with potentially benefic effects on performance.

Economic developments from the beginning of the millennium highlight *the transition phase* of the human society and mark the change from industrial society to information society. Materialized as a product of the "industrial revolution", the industrial society was based, among others, on the widespread introduction of machinery and manufacturing equipment in the economic activity, on the social division of labour, on creating technological assembly lines. The resources that have become the basis for this traditional society are tangible resources - capital, labour and natural factors. The Information Society (also called post-industrial society), is based on intangible resources, which have become a priority in recent years - information and knowledge. We cannot state that the industrial society lacked information, but we must acknowledge that the technological explosion during recent years made the information *a strategic resource*. Exponential amplification of knowledge and the rapid pace of renewal have made us reconsider the role of knowledge within the social development and its integration as one of the pillars in the formation and consolidation of the information society.

Such transformations occurring even “before our eyes" could not remain without an echo in the area of economic theory. Thus, there were a number of specialists (Alvin Toffler, Daniel Bell and others), who expected a severe decline of industrial activities, alongside with reducing the role of productive employment while consolidating the new information society. Nowadays we are witnessing a review of these theories, while generalizing the concept according to which current economic systems can not be entirely informational or post-industrial. Therefore, we can assert that material goods production activity will be continued, but there will be deep changes in production management, so that new concepts and production methods will become incompatible with current ones. In this context, we may identify the concerns for efficiency and flexibility of current production systems.

2. SERIAL PRODUCTION MANAGEMENT - GENERAL CHARACTERISTICS AND TRENDS OF EFFECTIVE MANAGEMENT

The principles and the methods applied in industrial production management differ according to the nature and quantity of the manufactured products, to the technological specialization of industrial subunits and also to other elements that characterize the typology of industrial production. For this reason, defining and characterizing the types of production has a particular importance for choosing the most appropriate models of industrial production management, in relation to the particularities of production processes taking place there.

By type of production we can understand an *organizational and functional status of the company due to the nomenclature of manufactured products, to the production volume executed on each heading of the schedule, to the degree of specialization of the company and to the movement of various raw materials, semi-*

finished products from one workstation to another (Bărbulescu, et al., 1995, p.150), (Deaconu, 1998, p.144), (Cârstea & Pârvu, 1999, p.87). In practice, we can identify three types of production, namely: mass production, serial production and small scale production.

Serial production is used in some enterprises which manufacture a relatively limited range of products; each product is manufactured in larger or smaller amounts (class of fabricated products). This production involves manufacturing the same products on assembly lines, so that it can be characterized using the following basic formula:

$$Q_i \cdot t_j \prec F_{ij} \quad (1)$$

where:

Q_i - represents the amount of “i” products manufactured in a certain period of time (usually one year);

t_j - time needed to carry out the task "j" for a unit of product "i";

F_{ij} - the period of time allotted for a workstation in order to carry out the task "j" on products such as "i" (covering the period in which the quantity Q_i is being manufactured).

In other words, the quantity of “i” products manufactured is not sufficient to ensure full workload of the workstation with one single operation - "j". Therefore, in order to make the most of the time, the workstation will be allotted several operations for different products. The greater the inequality $Q_i \prec F_{ij}$ is, the greater the number of different operations to be performed on the same workstation is. As a result, it reduces the degree of specialization of labour and passing raw materials from one workstation to another will be done in amounts equal to the size of the consignment.

According to the size of the batch of different products and to the manufacturing frequency, there are three possible types of serial production: *large series production, medium series production, small series production*. In order to pass the goods from one workstation to another, continuous means of transport are used (in the case of large series) or discontinuous ones (in the case of small series production). In companies with serial production, the layout of various machinery and equipment is homogeneous (for small batches) or there are assembly lines (for medium and large series production).

The main features of serial production could be summarized as follows (Jaba, 2002, p.273):

- production schedule is limited (the factory produces few types of product);
- production volume for each product type is great;
- the production process implies regular repeatability of certain type of products;
- batch production: certain estimated amounts of goods included in the schedule are launched into production simultaneously in the form of batches or series which alternately take turns at the workstation and at the production equipment.

Other features derive from these elements, features which are detailed in management and production economics textbooks.

In the context of this paper, the steps to efficient serial production management have set **batch production** as a starting point. Thus, the batch represents the quantity of identical products (parts, components, subassemblies, etc.) launched simultaneously into manufacturing; they are processed on the same workstations during the same period of preparation-finishing time (Moldoveanu, 1996). The preparation-finishing time includes: the time for filling out the papers necessary to launch products into manufacturing, the time to supply workstations with raw materials and with materials required for carrying out operations, the time to train workers or to study the technical documentation, the time to adjust the equipment and install new devices, the time to manufacture one or more sample products, the time necessary to deliver the products and bringing the workstation to its original condition.

If in the past batches represented, alongside with typification and standardization, one of the virtues of mass production, nowadays it can turn into a disadvantage against the expected changes in production systems, changes that marked the transition to the postindustrial society. Thus, it appears that in recent years, large series production has been facing significant difficulties arising especially from the strong outlet market dynamism and from the refinement of consumers' demands; this trend has been outlined both quantitatively and qualitatively. Widening the diversity production carries a direct impact on the production process, both from technological and organizational perspective, taking into account the fact that it requires more frequent changing from manufacturing one product type to another. These issues are particularly evident for small and medium series production, which weigh the strongest within the automobile industry (over 80% of total production).

It turns out that the concerns for *increasing the efficiency and flexibility* of production are greater; these attributes involve radical changes, both in management methods and in manufacturing technology. We shall dwell upon the two directions for improving serial production management: increasing economic efficiency by optimizing the size of batches and making production systems more flexible by implementing innovative methods to reduce the exchange of die.

3. INCREASING THE EFFICIENCY OF SERIAL PRODUCTION BY OPTIMIZING THE SIZE OF THE BATCH

The development of production processes within small and medium series production requires batches, considering the fact that a relatively large number of products types are manufactured and their beneficiaries may not require the entire annual amount of a particular type of product, instead they need smaller quantities that are to be available through consecutive deliveries in the long run. Batch production is dictated by the business conditions and by the need to carry out a more efficient activity. It is obvious that launching into production, at a single moment in time, of all the products of some class, would coincide with very long manufacturing cycles and with an immobilization - in large volume and over a long period of time – of the company funds in the form of unfinished production. Although medium series production represents the typical branch of batch production, it can also be found in large series production and in mass production organized in flow assembly lines. Determining the optimal size of the batch is a necessary step which has as a starting point the minimization of production costs as a key lever for increasing economic efficiency. Moreover, the production batch, due to its size, influences a series of efficiency indicators of the industrial activity such as: the usage of production capacities, the speed of working capital rotation, labour productivity, production costs and, ultimately, the profit (Constantinescu, et al., 1994, p.42).

Starting batch production brings about different types of production costs. First, the manufacturing of a new class of products requires some expenditure to carry out on the job preparatory-finishing operations. This category includes expenditure related to: elaborating the documentation needed for starting the production, supplying the workstations with the necessary materials and equipment, training workers and studying the technological documentation, adjusting the equipment, manufacturing one or more sample products, delivering the products and bringing the workstations to their original state, etc. If the unit cost is noted c_l, it verifies the equation:

$$c_l(n) = c_{pi}(n) = \frac{C_{pi}}{n} \tag{2}$$

where:
C_{pi} is the total cost for preparing and completing the batch manufacturing process (they bear the characteristic and the influence of conventional-constant expenditure);
n – the number of products within the batch;
$c_{pi}(n)$ – the unit costs for the preparation-finishing operations.

Drawing the graph corresponding to the equation (2), we obtain an equilateral hyperbola. The development of such a function shows that as the batch size increases, the costs per unit are reduced; the two figures are in inverse ratio.

In the case of two different batch sizes n_1 and n_2 (where $n_1 < n_2$), the launch unit costs are $\frac{C_{pi}}{n_1}$ and $\frac{C_{pi}}{n_2}$, respectively. The external economies of scale per unit resulting from the batch production of size n_2 is:

$$e = \frac{C_{pi}}{n_1} - \frac{C_{pi}}{n_2} = C_{pi} \cdot (\frac{1}{n_1} - \frac{1}{n_2}) \tag{3}$$

while the total external economies of scale are:

$$E = Q \cdot C_{pi} \cdot (\frac{1}{n_1} - \frac{1}{n_2}) \tag{4}$$

where:
Q represents the total quantity of a certain type of products estimated by the annual production programme of the company.

The external economies of scale identified by relations (3) and (4) could lead to the conclusion that in terms of launch costs, it is advantageous to work with batches of bigger size. Thus, the production process would require a substantial amount of current assets available over a long period of time, resulting in significant losses. The equation of losses has a linear form:

$$c_2(n) = I \cdot n \tag{5}$$

where:
I represents the losses per product (lei).

The graph of the losses per product shows a line starting at the origins and rising as the production batch increases.

The unit cost of the working capital in the form of unfinished production is calculated using the following formula:

$$c_2(n) = c_i(n) = \frac{V \cdot T \cdot \delta}{n} \tag{6}$$

where:
V represents the value of net current assets in the form of unfinished production (lei);
T - duration of blockage (days)
δ - the losses registered by the company as a result of blocking the working capital (percentage of 1 lei/day).

In its turn, the value of blocked current assets (V) for a batch of size "n" will be:

$$V = n \cdot (C_a + \frac{C_p}{2}) \tag{7}$$

where:
C_a - the cost of the operation prior to starting the batch production (lei/piece)
C_p - the cost of processing one product from the batch (lei/piece).

Processing costs are taken into consideration at half their value because the amounts are not paid right on the spot; they increase linearly for each object from zero to the maximum value which equals C_p in a period of time t. The average size of the processing cost results from the relationship:

$$C_p = \frac{\int_0^t \frac{C_p x}{t} dx}{\int_0^t t dx} = \frac{C_p \cdot \frac{t^2}{2 \cdot t}}{t} = \frac{C_p}{2} \tag{8}$$

The period of time for which the current assets (T) were blocked in order to manufacture the batch (n) during period t is determined by the formula:

$$T = \frac{t}{n_l} \tag{9}$$

where:

n_l - the number of lots released during period T

t – the deadline of the production programme (days).

Starting from $n_l = \frac{Q}{n}$, it is immediately apparent that:

$$T = \frac{t \cdot n}{Q} \tag{10}$$

Replacing the analytical relations of parameters V and T in the equation of the expenditure regarding the blockage of circulating capital (6), we obtain:

$$c_i(n) = n \cdot (C_a + \frac{C_p}{2}) \cdot \frac{t \cdot n}{Q} \cdot \delta \tag{11}$$

The total losses caused by blockage will be:

$$C_i(n) = n \cdot (C_a + \frac{C_p}{2}) \cdot \frac{t \cdot n}{Q} \cdot \delta \cdot n_l \tag{12}$$

Substituting $n_l = \frac{Q}{n}$ in equation (12), we obtain the final expression of the total losses caused by blocking the working capital:

$$C_i(n) = n \cdot (C_a + \frac{C_p}{2}) \cdot t \cdot \delta \tag{13}$$

As a consequence, losses caused by blockage are directly proportional to the size of the batch, while the loss caused by increasing the lot from n_1 to n_2 will be:

$$Pi = C_i(n_2) - C_i(n_1) = (n_2 - n_1)(C_a + \frac{C_p}{2}) \cdot t \cdot \delta \tag{14}$$

In order that the transition to large batches production be more effective, it is necessary for the loss calculated using the relation (14) to be compensated by the savings made with preparation-finishing operations and to be evaluated using the relation (4).

The equation of the total production costs of one product from the batch $C_t(n)$ results from summing up the launch costs and the costs corresponding to blocking the working capital:

$$C_t(n) = \frac{C_{pi}}{n} + \frac{n \cdot (C_a + \frac{C_p}{2}) \cdot t \cdot \delta}{Q} \qquad (15)$$

Let us note $a = \frac{(C_a + \frac{C_p}{2}) \cdot t \cdot \delta}{Q}$ and $C_{pi} = b$.

Hence it follows:

$$C_t(n) = a \cdot n + \frac{b}{n} \qquad (16)$$

The determination of the optimal batch size requires the minimization of the expression $C_t(n)$. The solution can be presented both graphically and based on an analytical calculation. The graphical method implies drawing two curves representing the evolution of the two factors of the sum (16). Hence, we have figure 3.

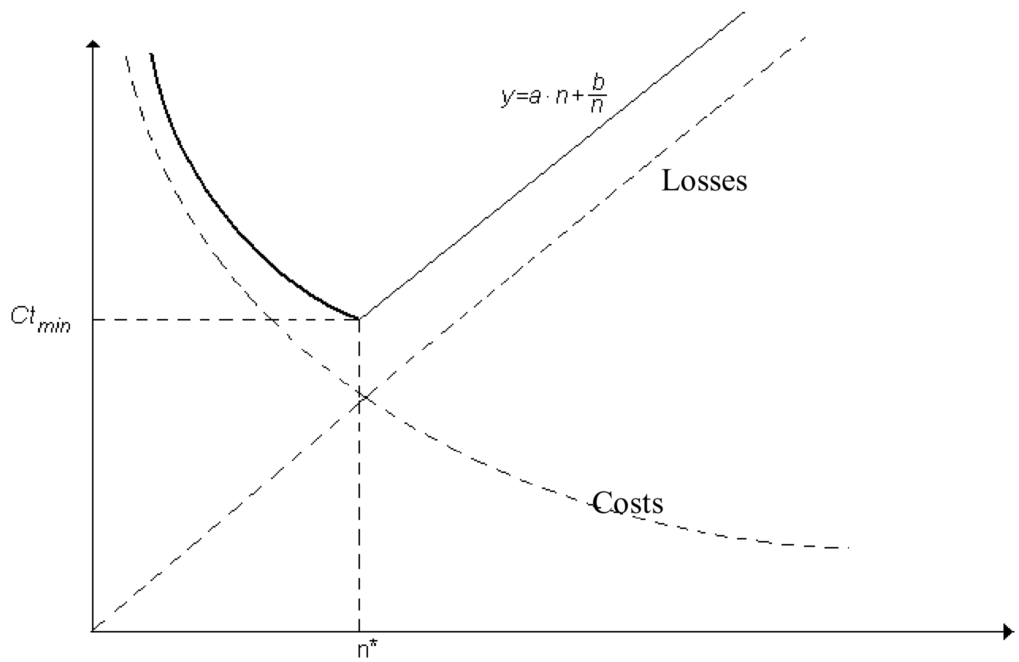

Figure 1. Total cost per product unit and the optimum production batch

Analytically, we can calculate the first derivative in relation to n of the total cost function and then the result is set to zero:

$$\frac{dC_t(n)}{dn} = -\frac{b}{n^2} + a = -\frac{C_{pi}}{n^2} + \frac{(C_a + \frac{C_p}{2}) \cdot t \cdot \delta}{Q} \quad (17)$$

For the total cost function $C_t(n)$ to reach its minimum, the following condition must be met:

$$\frac{dC_t(n)}{dn} = 0 \quad (18)$$

Solving the equation above, we obtain the equation for determining the optimal batch size (n^*):

$$n^* = \sqrt{\frac{C_{pi} \cdot Q}{(C_a + \frac{C_p}{2}) \cdot t \cdot \delta}} \quad (19)$$

The problems of determining the optimum batch often lead to simple calculations that can be applied immediately. However, there are situations when necessary calculations are already performed and organized in tables or monograms. But the practice does not always use the sizes of batches resulted from optimal mathematical calculations because in the case of a large number of items there are difficulties related to the operational planning of production and to ensuring its rythmicity.

In addition, the organizational framework of each company puts forward additional restrictions that should be taken into account when determining the manufacturing batch size. Therefore, the calculated batch size needs to undergo a process of correction or adjustment, taking into account the peculiarities of the production process organization within each company. Corrected lots are called *economic lots*. Practical experience has shown that the economic lot may differ from the optimal one by a margin of ± 10-15%, and the deviations reported in the batch management costs are not significant (Cârstea & Pârvu, 1999)[*].

Analyzing the final relation for calculating the optimal batch - relation (19) – we conclude that the only real and economic option to reduce the batch to a size which is considered to be effective is *reducing preparation-finishing costs* and hence the time spent. In this respect, modern science of production management provides practitioners

[*] *The abridgement SMED was not originally included in Shingo's paper (called "Shingo System – the Key to Improve Production"), but it was used in 1985 when the book was translated into English. SMED means "Single Minute Exchange of Die", a word-for-word translation being "converting a manufacturing process from running the current product to running the next product in a single-digit minute".*

with different tools to meet the need of solving specific problems. SMED method suggests that by using specific techniques, one can minimize change-over time.

4. FLEXIBLE SERIAL PRODUCTION USING SMED METHOD

SMED method* (SINGLE MINUTE EXCHANGE OF DIE) is part of the Just-in-time production management methods and was elaborated by the Japanese specialist Schigeo Schingo. The aim of this method was to reduce change-over time for the series of fabricated products, or to automatically convert a manufacturing process within Mazda factories. The implementation of SMED method improves production flexibility through a rapid changeover, taking into consideration the fact that in the case of traditional production processes such changes take a rather long period of time, they are complex and are performed by highly qualified workers.

The essential premise for applying this method is to make the distinction between the two types of operations involved in the change-over, namely:

- *input exchange die*, performed only when the equipment is idle and therefore production is stopped. This category of time, directly related to the physical changeover can be reduced by standardizing the tool clamping systems, by avoiding the use of threaded adjustment devices with long-haul and by synchronizing operations etc.;
- *output exchange die*, which can be performed while the production process is still running. The time allotted for external operations represents 70% of the total change-over time and it can be converted to "masked time", that is to say it also covers the time when technological operations are performed on the previous batch.

The steps imposed by the practical implementation of Schingo's method involve carrying out the following tasks:

- detailed analysis of each operation and the determination of the time required for its execution;
- separate internal from external setup operations and performing the latter outside the changeover time;
- converting internal to external setup by improving labour organization;
- standardizing functions to be changed and minimizing changeover time;
- eliminate adjustments and mechanization.

Due to immediate potential impact on productivity growth and on changeover time and costs, the implementation of SMED method is applied in production processes characterized by large changeover times that affect the technological flow. Effective implementation of Schingo's method in companies such as Mitsubishi, Toyota and Fichet-Bauche, has resulted in dramatic reduction of changeover times (by about 100-200 times). For example, Toyota has replaced the press machine which required a few hours to change dies with a punching machine equipped with multiple dies which allowed converting the process of turning out Celica automobiles to turning out Corola automobiles (or any other car from Toyota brand) within only two minutes; this had a very positive impact on improving profitability and production flexibility.

5. CONCLUSION

In recent years, we have witnessed a slow transition of traditional manufacturing systems to a higher form of operation management, based on advanced production systems. New strategic orientation of the production responds to market signals; under the circumstances, the role of batch production should not be limited to repetitive delivery of identical, standardized parts, but must extend to providing goods and services closely adapted to customers' orders. Therefore, the optimal size of batches and the reduction of changeover time are the main prerequisites for serial production flexibility.

The optimization calculations presented in the paper can be applied with good results in the case of those enterprises in which the production process includes a series of processing stages for converting raw materials into finished products. This category includes machine-building factories, furniture factories, textiles companies and factories specialized in producing household appliances, etc. There are other situations when the general model for minimizing production costs can be customized: it is the case of companies that turn small items the consumption period of which exceeds the period of production; industrial enterprises where the production period should not be neglected as compared with the duration of consumption and production rates and consumption rates are not equal; companies that have certain features as regards the relation between the average production rate and the average sales rate (Jaba, 2002).

Regardless of the situation, determining the optimal manufacturing batch size must be correlated with the issue of reducing the changeover time. This is all because the studies made by specialized literature (Bărbulescu, 2000) revealed that the size of a batch is proportional to the launch cost which is influenced, in its turn, by the time needed to stop the machinery for adjustments. In order to reduce changeover time by 50%, the batch size should be reduced by 70% as compared to the initial economic batch quantity; for a reduction by 75% of the changeover time, the batch launched into to manufacturing represents 50 % of the estimated optimal lot. It is thus obvious that in order to reduce changeover times it is necessary to reduce manufacturing batch sizes, a trend that meets at the same time the requirements imposed by increasing production flexibility.

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