

# Econometric Considerations on the Wear Degree of Production Capacity

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## Abstract

*The management planning and control are essential elements, because the time interval needed for making decisions varies a lot, from a few years to a few days or even hours. The purpose of this paper is to use the econometric analysis to make the decision of replacing some production equipment of aleatory wear within a company.*

**Key words:** *fixed capital, decision, producer equipment, production capacity, to replace, best estimator, econometric model*

## Economic Considerations and Notations

Reaching all management goals means making intelligent decisions and knowing the decision limits. This means knowing the necessary conditions for making a new optimal decision. The management planning and control are essential elements, because the time interval needed for making decisions varies a lot.

An important part in the structure of the physical capital is played by the category of the production equipment. After labour, the production equipment is the most economic production factor, therefore no normal production activity can take place without its proper course. To obtain a certain product, certain units must be used, units that act on the dressed object, and the wear of the production equipments leads to the decrease in production, and may also reduce the quality of the resulted products.

The producer is interested, when necessary, in the replacement of the production equipments. The operation could take place either by stopping the production process completely, or by partially stopping it.

The disadvantages of this approach are:

- The possible raw and material stockpiles depreciation during the drift cycle;
- The diminution of the offer for that certain product, which means that the risk of total or partial market segment loss may appear;
- The loss of qualified staff that becomes inactive during the replacement process.

The second option that is being taken into account is the replacement of one or more production machines, while their tasks are taken over by the remaining machines. To complete this type of task, the following certain economic aspects must be considered:

- The possibility for the producer to have more than one production equipment that produce the same type of product at the same time;
- The used machines have different degrees of wear that reduces the production capacity and they are not completely loaded;
- The product necessary on the market is assured, which might not happen without an investment. The investment effort is all about the new production equipment, because the space left empty by the replaced old machines can be reused.
- After the replacing cycle, the producer has the goal to satisfy the future necessary of products, and to use the new machines (and the ones that he did not replace) for the future production.

If the producer has  $n$  machines,  $U_j$ ,  $j = \overline{1, n}$  then  $Q_{U_j}$  is the maximum production capacity at the moment considered initial for the replacement, and  $C_{U_j}$  represents the expenses for the production, the expenses strictly connected to the use of the  $U_j$  machine.

Considering that the new production equipments are the same type as the ones that are to be replaced and  $\overline{Q}$  is the production capacity given by the technical documents for new production equipment. Considering  $P_0$  as representing the present demand for the product taken into account that can be satisfied by the present production, and  $P_v$  is the predicted production considered to be necessary for a period longer than the one needed for replacing the old machines.

Some of the machines run during the replacement and others do not. To make a difference between the machines, the  $VS \in \{0,1\}^n$  state vector, defined by  $VS = (VS_1, VS_2, \dots, VS_n)$ , where:

$$VS_j = \begin{cases} 0, & \text{if the machine } j \text{ is stop } p \text{ ed} \\ 1, & \text{if the machine } j \text{ works} \end{cases}, \quad j = \overline{1, n} \quad (1)$$

Assuming that the production process may not be entirely taken over by the new production equipments, then the maximum number of machines that are to be replaced is established using the following relation:

$$m = \left[ \frac{P_v}{\overline{Q}} \right] + 1 \quad (2)$$

where  $\left[ \frac{P_v}{\overline{Q}} \right]$  is the round part of  $\frac{P_v}{\overline{Q}}$ .

## The Econometric Model

The mathematical aspect of the impossibility to assure the necessary products in the future is:

$$\sum_{j=1}^n Q_{U_j} < P_v \quad (3)$$

The mathematical model can be used if the  $P_0$  production is assured considering that one or more machines are stopped, meaning that  $i \in \{1, 2, \dots, n\}$  exists, so that:

$$\sum_{j \neq i}^n Q_{U_j} \geq P_0 \quad (4)$$

If relation (4) is completed by one machine  $U_i$  then:

$$VS_j = \begin{cases} 0, & j = i \\ 1, & j \neq i \end{cases} \quad j = \overline{1, n} \quad (5)$$

which gives a solution for the model:

If relation (4) is completed, it means that for each  $j$  there is a vector having the (5) properties and it assures a possible solution. The problem to be solved is the determination of a vector that could give an optimal solution.

The necessary production is created if the  $VS$  vectors execute the condition:

$$\sum_{j \neq i}^n (Q_{U_j} \cdot VS_j) \geq P_0 \quad (4')$$

It is necessary that the predicted  $P_v$  production is created by the new machines and by the ones that have not been replaced, at the end of the replacement cycle, which means that:

$$\sum_{j=1}^n Q_{U_j} \cdot VS_j + \overline{Q} \left( n - \sum_{j=1}^n VS_j \right) \geq P_v \quad (6)$$

The optimal value for the problem is given by the  $VS$  vector. The production expenses of the equipments that have not been replaced should be minimum for this vector, which means it should be possible for the goal function:

$$f = \sum_{j=1}^n (C_{U_j} \cdot VS_j) \quad (7)$$

to be minimized.

## Example of the Model Application

A company uses six similar machines that independently produce the same product. At the moment considered initial for the replacement, the machines can produce  $Q_{U_j}$ ,  $j = \overline{1, 6}$  pieces, presented in table 1. The product necessary for the initial moment is of 3760 pieces.

The expenses strictly connected to the proper functioning of the machines  $C_{U_j}$  m. u.,  $j = \overline{1,6}$  are presented in table 1. The necessary number of products in the future is of 7100 pieces, a new machine can produce 5750 pieces (according to the manual).

The problem is to decide, which machines must be replaced without reducing the current production so that the expenses are minimum and the predicted production is obtained.

**Table 1.** Initial data

Machine number	1	2	3	4	5	6
$Q_{U_j}$	690	780	695	610	900	860
$C_{U_j}$	198 5	287 0	222 0	259 0	399 0	291 0

The data independent from the machines that are found in the replacement equation are  $\bar{Q} = 5750$ ,  $P_0 = 3760$ ,  $P_v = 7100$ . Condition (3) is executed:

$$\sum_{j=1}^6 Q_{U_j} = 4535 < 7100 = P_v$$

And for  $j \neq 4$  condition (4) becomes:

$$\sum_{\substack{j=1 \\ j \neq 4}}^6 Q_{U_j} = 690 + 780 + 695 + 900 + 860 = 3925 \geq 3760 = P_0$$

which means that it is executed.

It can be seen that for  $j=3$  the condition is also executed:

$$\sum_{\substack{j=1 \\ j \neq 3}}^6 Q_{U_j} = 3840 \geq 3760 = P_0$$

This means that the execution of the condition for more than one value of  $j$  assures the existence of more admissible vectors  $VS$ , therefore there is an effective problem as far as the optimum value is concerned.

Using the result form relation (2),  $m = \left\lceil \frac{7100}{5750} \right\rceil + 1 = 2$ , it can be said that by replacing at least two machines, the demand can be satisfied  $P_v = 7100$ , because the production can be obtained by the new equipments.

The number of values for vector  $VS = (VS_j)_{j=\overline{1,6}}$  is  $C_6^1 + C_6^2 = 21$  compared to the entire number of possibilities  $2^6 - 2 = 62$ , when the value of  $m$  is not taken into account.

Table 2 presents the possible values for vector  $VS$ , values for the model restriction and for the case when the restriction is controlled, and the calculated value for the goal function.

**Table 2.** The results of the model application

Case	VS	Restriction current production	$P_v$	F Value
1	(0,1,1,1,1,1)	3845 $\geq$ 3760 YES	9595 $\geq$ 7100	14580
2	(0,0,1,1,1,1)	3065 $\geq$ 3760 NO	–	–
3	(0,1,0,1,1,1)	3150 $\geq$ 3760 NO	–	–
4	(0,1,1,0,1,1)	3235 $\geq$ 3760 NO	–	–
5	(0,1,1,1,0,1)	2945 $\geq$ 3760 NO	–	–
6	(0,1,1,1,1,0)	2985 $\geq$ 3760 NO	–	–
7	(1,0,1,1,1,1)	3755 $\geq$ 3760 NO	–	–
8	(1,0,0,1,1,1)	3060 $\geq$ 3760 NO	–	–
9	(1,0,1,0,1,1)	3145 $\geq$ 3760 NO	–	–
10	(1,0,1,1,0,1)	2855 $\geq$ 3760 NO	–	–
11	(1,0,1,1,1,0)	2895 $\geq$ 3760 NO	–	–
12	(1,1,0,1,1,1)	3840 $\geq$ 3760 YES	9590 $\geq$ 7100	14345
13	(1,1,0,0,1,1)	3230 $\geq$ 3760 NO	–	–
14	(1,1,0,1,0,1)	2940 $\geq$ 3760 NO	–	–
15	(1,1,0,1,1,0)	2980 $\geq$ 3760 NO	–	–
16	(1,1,1,0,1,1)	3840 $\geq$ 3760 YES	9590 $\geq$ 7100	13975
17	(1,1,1,0,0,1)	3025 $\geq$ 3760 NO	–	–
18	(1,1,1,0,1,0)	3065 $\geq$ 3760 NO	–	–
19	(1,1,1,1,0,1)	3635 $\geq$ 3760 NO	–	–
20	(1,1,1,1,0,0)	2775 $\geq$ 3760 NO	–	–
21	(1,1,1,1,1,0)	3675 $\geq$ 3760 NO	–	–

The minimum value of the goal function is 13 975 and it is reached for (1,1,1,0,1,1), which represents the optimal searched value. The VS vector for which the set goal is reached indicates the stopping of machine number 4 for the replacement.

If the number of machines is higher, the presented algorithm is not convenient any more.

## Conclusions

The planning of technological processes has the goal to generate similar products, which have to contain the features of product project. The activity of quality assurance assesses the level of fidelity in reproducing the conceptual model, which represents the final goal of technological process. It is possible to obtain a high level of fidelity through a certified technological process and by subsequent optimization of the process from an economic point of view. Some variations in the quality of the products occur along production processes due to attrition of equipments, which must be replaced so that the current production should not undergo major changes and the production expenses should be low.

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## Considerații econometrice privind gradul de utilizare a utilajelor de producție

### **Rezumat**

*Planificarea și controlul în management sunt elemente esențiale deoarece intervalul de timp pentru luarea deciziilor variază foarte mult, de la câțiva ani la câteva zile sau uneori ore. Scopul acestui articol este reprezentat de utilizarea analizei econometrice în luarea deciziei de înlocuire a unui echipament de producție cu uzură aleatoare în cadrul unei societăți comerciale.*