Basing the Decisions Regarding the Optimal Variant of the Maintenance Policy Based on the Criterion of Economic Costs

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Abstract

By maintenance we mean a set of technical-organizational activities, whose purpose is to ensure maximum performance for the good considered (equipment, building, installation, etc.) Based on these considerations, the aim of this work is to make the most susteinable decisions in choosing maintenance methods based on economic costs. The purpose of predictive maintenance is to predict when equipment failures may occur, depending on a number of factors, followed by the prevention of these failures through correct and regular maintenance. By having these scheduled operations, excessive maintenance (an unnecessary cost) and unexpected breakdown of the equipment are eliminated at the same time. Also, the lifespan of an equipment is increased when it is maintained before defects appear.

Key words: maintenance, productive potential, technical infrastructure
J.E.L. classification: D11, D23

1. Introduction

The development of human society was accompanied by a strong revolution in the technical field, being supported by the development of this type of activity. This is where the need for support activities arose from which maintenance cannot be missing.

A few definitions are instructive.

A. According to Grand dictionnaire universel XIX siecle by Pierre Larousse, Paris, 1873:

• Maintenir (to maintain) – conservation, defense, protection.....

• Entretien (maintenance) – soin qu□on consacre.....(what is undertaken to keep something in good condition.....);

• Reparation (repair) – action de remise en marche .....(action to restore operation.....);

B. According to the Encyclopaedia Brittanica: (Ceaușu, 1980, p.77)

• Maintenance – to hold in an existing state .....(to maintain in the existing state);

• Repair (repair) – to restore to the good condition.....(to bring back to good conditions);

• Entertain (empowerment) – to maintain in a good condition.....(to maintain in good condition).

C. A preliminary observation is that there is a significant difference between "maintenance" and "maintenance" and repair, an aspect also noted in the Explanatory Dictionary of the Romanian language:

• To maintain - to keep something in the same state or form in which it is at a given moment, to make it last...;

• To maintain - to keep in good condition, in good conditions; to make last, to maintain;

• To repair – to make one's own for use, to restore, to maintain.....

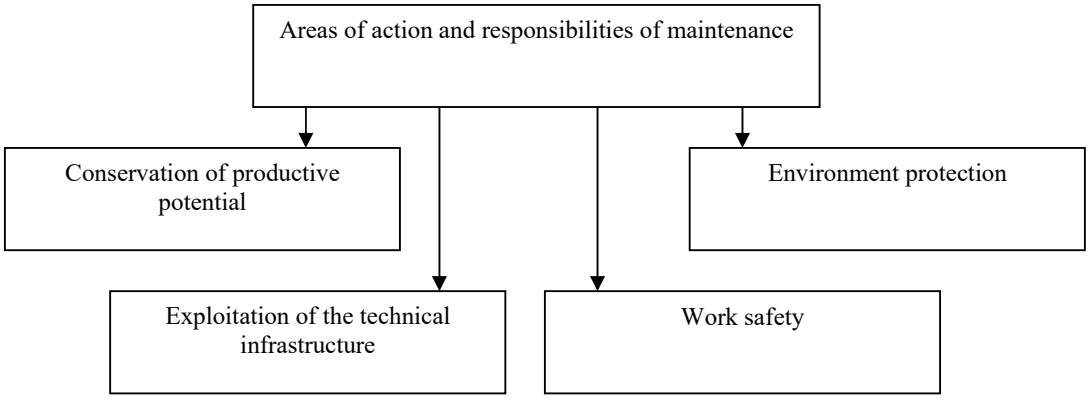
The Romanian terms shown in the aforementioned dictionary originate in French; in the consequently, it can be considered that the term "maintenance" finds its justification in the current language with some remarks (Burloiu, 1997, p. 63)

• maintenance involves maintenance and repair activities;

• it is erroneous to admit that only the performance of maintenance and repair activities represents "maintenance". By maintenance we understand a set of technical-organizational activities, which aim to ensure maximum performance for the asset in question (machinery, building, installation, etc.).

These activities are grouped by areas of action and responsibility.

Figure no. 1. The areas of action and responsibility of maintenance



Source: Authors' contribution

Let's present them one by one:

a) **Preservation of productive potential.** In order to ensure the productive potential of the transport enterprise, the responsibilities maintenance is embodied in actions aimed at: (Ceaușu, 1980, p. 211)

- the permanent diagnosis of the technical condition of the machines and installations;
- remedying the detected dysfunctions;
- repairing and commissioning the equipment in case of breakdown;
- carrying out installation activities, arrangement, design of new maintenance methods in order to optimally use the new equipment.

These purely technical activities will be based on strategies and management policies specific to maintenance.

The assessment of efficiency is carried out in accordance with a series of specific performance assessment indicators.

b) **Exploitation of the technical infrastructure.** The technical infrastructure means the set of sewerage, storage and distribution of the units necessary to carry out the specific activities of the company (electrical, thermal, water installations, pressurized air, steam, gas, etc.).

Within this field, activities related to: (Golea, 2008, 9.39)

- permanent diagnosis of the general state of operation of utility networks;
- designing and installing new utility networks;
- quality and quantity control of the transported fluid;
- reduction of consumption and losses in the transport and distribution of utilities.

In the spirit of the activities described above, some authors consider that in this category of activities, the operation of the company's logistics park must also be introduced, in which case the logistics function is combined with the maintenance function.

In other approaches, the logistics activity is considered to be itself a basic function of the enterprise, assisted by the maintenance function in a similar way to the production function.

In the classic organization of the majority of Romanian enterprises, there is an organization that presupposes the existence of a "mechanical-energetic" compartment and another "logistics" compartment. (Hlaciuc, 1999, p. 98)

c) **Environmental protection.** By its nature, a maintenance service must only carry out activities that are in accordance with the principles of respect for man and his environment. In this sense, the specific activities that per excellence belong to the department are: (Golea, 2012, p, 109)

- the permanent diagnosis of the technical condition of the machines and installations regarding the emanation of noxes;
- prevention of fluid leaks;
- permanent control of the level of pollution due to the specific activities of the enterprise and taking measures to bring it within the legal limits;
- maintenance and operation of recycling, recovery, filtration, etc. installations. of residual fluids.

In many maintenance management approaches, service quality is tight related to their implications on the environment.

d) **Work security.** Work security, referred to in current concepts as "safety and health at work" is the subject of multiple laws, decrees or government decisions that regulate the safe operation of machines and installations specific to each branch.

Although the rules regarding safety and health at work are addressed directly to the people involved in the management and exploitation of different types of equipment, we believe that the maintenance service has major implications in ensuring safety and health at work through specific activities such as: (Verzea et al, 1999, p. 106)

- maintaining in good working order the alarm devices specific to different types of machines or installations;
- the overall maintenance of the equipment, to prevent the occurrence of risks of accidents and occupational diseases specific to the work equipment that may endanger the operating personnel;
- the development of internal work safety rules, in accordance with any change made in the basic structure of the machinery during repair or modernization;
- carrying out studies regarding the security of the exploitation of new types of machines and the elaboration of specific rules;
- the development of quick intervention methods and in full security of personnel and fixed assets.

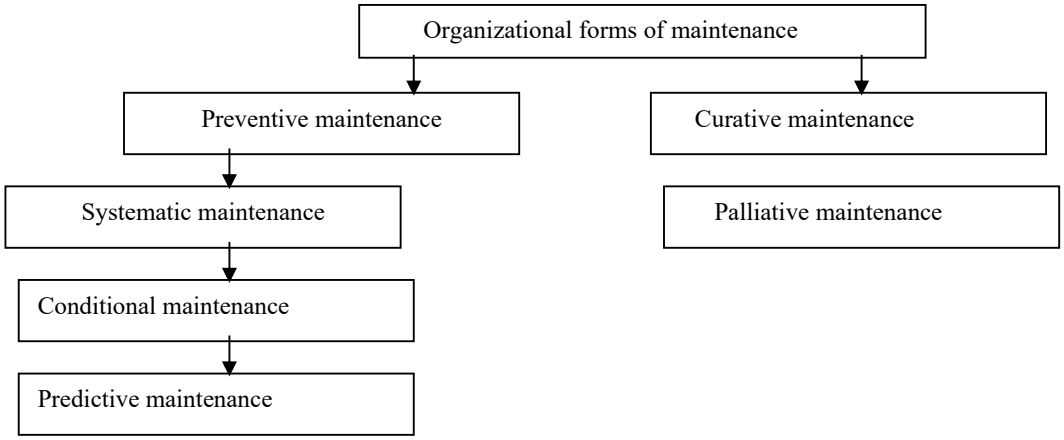
In all the maintenance activities carried out in a company, the safety of the staff will be considered above productivity or cost issues.

Moreover, in modern management, safety and health at work are considered to be active factors for motivating employees.

2. Theoretical background

The organization of maintenance activities is based on the following aspects: location of the enterprise; activity profile; the characteristics of the existing means of production.

Figure no. 2. Organizational forms of maintenance



Source: Authors' contribution

- **Preventive maintenance** is "maintenance whose object is to reduce the probability of failure or degradation of a good or service".

The types of preventive maintenance that we can remember are the following: (Hlaciuc, 1999, p. 83)

Systematic maintenance - respectively maintenance carried out through activities of maintenance, current repairs, revisions and capital repairs, constituted in a standardized technical plan of interventions specific to each type of machine.

Conditional maintenance - with the meaning of "maintenance carried out through the medium tracking the wear parameters of the key elements or sub-assemblies of the machines, by means of specific instruments (wear, vibration, oil analyzers etc.)" following that the maintenance interventions are carried out before the appearance of the defect.

Predictive maintenance - represents "subordinate preventive maintenance, the analysis of the evolution followed by the significant parameters of the degradation of the good that allows the delay and the planning of the interventions".

- **Corrective maintenance** represents "the set of activities carried out after the failure of a means of production or after the degradation of its function in an unforeseen way. These activities consist in the location of defects and their diagnosis, putting them back into operation with or without modifications and checking the proper functioning".

It is divided into two subtypes: (Lungu et al, 2004, p. 202)

Curative maintenance represents the set of maintenance activities corrective actions that have as their object, the restoration of a means of production in a specific state of operation, which allows it to fulfill its functions". (Bărbulescu, 1980, p. 182)

These activities can be repairs, modifications or arrangements aimed at eliminating defects.

Palliative maintenance represents "corrective maintenance activities aimed at allows a means of production, provisionally, to fully or partially fulfill its functions".

Troubleshooting is currently called for, this palliative maintenance mainly consisting of temporary actions that must be followed by curative actions.

A way to compare the efficiency of the previously stated systems can be achieved by means of the total average maintenance costs per unit of time.

3. Research methodology

The technical data necessary to run the study can be taken from the operating regulations of the machine, and those related to costs can be obtained from the economic manager.

The following data are known: (Lungu et al, 2004, passim)

- the cost of a preventive intervention on a machine is 30,000 lei;
- if the car were to break down (breakdown with medium complexity), it is estimated that putting it back into operation would cost 200,000 lei;
- at a standard operating time of 10,000 hours, the MTBF would be 200 hours;
- if a systematic maintenance would be applied, the failure probability F(t) would be 0.3 corresponding to an average duration of use m(t) of 300 hours;
- for the maintenance of this type of machine, a control device of the technological operating parameters for the main sub-assemblies can be used, which costs 400,000 lei for a guaranteed operating time of 2000 operating hours;
- a conditional intervention is estimated to have a cost of 1,000 lei, leading to a Kc coefficient of 1.5;
- the latest types of devices for general tracking of operating parameters cost 1,200,000 lei, but the manufacturer guarantees for 4,000 hours of operation, a Kp coefficient of 1.9 at the same cost of applying the method;
- part of the machines are with the normal operating time exceeded as a result, with all the efforts it is not possible to obtain an MTBF lower than 50 hours;
- new machines are guaranteed for a duration of operation of 1000 hours.

Based on the above information, a comparative analysis of the different maintenance policies that can be applied to the machine will be attempted.

4. Findings

According to relation (1), **the average total cost for curative maintenance** per time unit is:

$$C_{11} = \frac{p + P}{MTBF}\left[\frac{lei}{ora}\right] = \frac{30.000 + 200.000}{200} = 1.150\left[\frac{lei}{ora}\right] \quad (1)$$

where:
p- the cost of a preventive intervention on a machine – 30,000 lei
P - the cost of putting the machine back into operation - 200,000 lei.
MTBF – mean times of good operation – 200 hours.

If the machines were to be used beyond the normal operating time, ***the average cost of palliative maintenance*** per time unit relationship (2) will be:

$$C_{12} = \frac{p + P^{/}}{MTBF^{/}}\left[\frac{lei}{ora}\right] = \frac{30.000 + 200.000}{50} = 4.600\left[\frac{lei}{ora}\right] \quad (2)$$

where:
p – the cost of a preventive repair - 30,000 lei;
P□- additional cost borne in case of machine failure (lei) - P- 200,000 lei;
MTBF□ - the average time of good operation, after the standard period (much lower than MTBF) - 50 lei

The use of ***systematic maintenance*** generates the following costs:

$$C_{21} = \frac{p + P \times F(t)}{m(t)}\left[\frac{lei}{ora}\right] = \frac{30.000 + 200.000 \times 0,3}{300} = 300\left[\frac{lei}{ora}\right]$$

where:
p – the cost of a preventive repair - 30,000 lei;
P - the cost of putting the machine back into operation - 200,000 lei;
F(t) = probability of failure of the considered critical element during the service period t – 0.3;
m(t)=average duration of use of the considered critical element (hours) – 300 hours

If we opt for the purchase of a measuring and control device, the cost of applying ***conditional maintenance*** g becomes:

$$g = \frac{P_{disp\ ctrl}}{Df_{disp\ ctrl}} \times MTBF + P_{int\ erv\ cond} = \frac{400.000}{2000} \times 200 + 10.000 = 50.000\ lei$$

The calculation data were:
Pdisp ctrl - control device cost - 400,000 lei;
Df disp ctrl - guaranteed operating time of control device - 2000 hours;
MTFB - the average time of good operation of the machine - 200 hours;
P interv cond - conditional intervention cost - 10,000 lei.
As a result, the average total cost of conditional maintenance is:

$$C_{22} = \frac{p + g}{Kc \times MTBF}\left[\frac{lei}{ora}\right] = \frac{30.000 + 50.000}{1,5 \times 200} = 267\left[\frac{lei}{ora}\right]$$

where:
p – the cost of a preventive repair - 30,000 lei;

g- the cost of applying the conditional maintenance, expressed as the sum of the expenses for purchasing the necessary sensors and sensors and for reading, decoding and interpreting the collected data -50,000 lei;

Kc=coefficient of conditional intervention, which usually increases MTBF- 1.5.

The application of ***predictive maintenance*** methods will lead to expenses g calculated as:

$$g = \frac{P_{disp\ ctrl}}{Df_{disp\ ctrl}} \times MTBF + P_{int\ erv\ cond} = \frac{1.200.000}{4000} \times 200 + 10.000 = 70.000\ lei$$

The calculation data were:
Pdisp ctrl - control device cost - 1,200,000 lei;
Df disp ctrl - guaranteed operating time of control device - 4000 hours;
MTFB - the average time of good operation of the machine - 200 hours;
P interv cond - conditional intervention cost - 10,000 lei.
Consequently, the average forecast maintenance cost per time unit will be:

$$C_{23} = \frac{p+g}{Kp \times MTBF}\left[\frac{lei}{ora}\right] = \frac{30.000 + 70.000}{1{,}9 \times 200} = 263\left[\frac{lei}{ora}\right]$$

where:
p – the cost of a preventive repair - 30,000 lei;
g- the cost of the latest devices for tracking the operating parameters -70,000 lei;
Kc=coefficient of conditional intervention, which usually increases MTBF- 1.9.

Let's make the following summary table:

Table no. 3.1 Centralization of results

Average total cost of curative mainte-nance per time unit	"the set of corrective maintenance activities whose object is to restore a means of production to a specific state of operation, which allows it to fulfill its functions". These activities can be repairs, modifications or arrangements aimed at eliminating defects.	1.150 $\left[\frac{lei}{ora}\right]$
Average total cost of palliative maintenance	. Palliative maintenance represents "corrective maintenance activities intended to allow a means of production, provisionally, to fully or partially fulfill its functions". Troubleshooting is routinely called for, this palliative maintenance mainly consisting of temporary actions that must be followed by curative actions	4.600 $\left[\frac{lei}{ora}\right]$
Average total cost of systematic maintenance	The maintenance carried out through maintenance activities, current repairs, revisions and capital repairs, constituted in a technical plan standardized by interventions specific to each type of machine.	300 $\left[\frac{lei}{ora}\right]$
Average total cost of conditional maintenance	Maintenance carried out through the medium tracking the wear parameters of the key elements or sub-assemblies of the machines, by means of specific instruments (wear, vibration, oil analyzers etc.)" following that the maintenance interventions are carried out before the appearance of the defect.	267 $\left[\frac{lei}{ora}\right]$
Average total cost of predictive maintenance	It represents "subordinate preventive maintenance." the analysis of the evolution followed by the significant parameters of the degradation of the good that allows the delay and the planning of the interventions".	263 $\left[\frac{lei}{ora}\right]$

Source: Authors' contribution

5. Conclusions

From the data analysis it is found that:

- the most economical maintenance policy is the predictive one (263 lei/hour); however, this involves the purchase of an AMC which is currently expensive but shows its effectiveness over time;
- with a much smaller investment, you can opt for conditional maintenance, which will also lead to reduced costs, close to those of predictive maintenance - 267 lei/hour;
- if there are no funds available for the application of conditional maintenance, then systematic maintenance is the most convenient from the point of view of the hourly cost (300 lei/hour);
- curative and palliative maintenance is expensive, determining average total costs of 1,150 lei/hour, respectively 4,600 lei/hour.

If the machines are in the warranty period, we can consider that MTBF = 1000 hours, consider and consider only preventive interventions ,3,000 lei, then the average cost per time unit is:

$$C_{11} = \frac{p}{MTBF}\left[\frac{lei}{ora}\right] = \frac{30.000}{1.000} = 30\left[\frac{lei}{ora}\right]$$

We should resort to replacing the machine at MTFB, but this will lead to particularly high investment costs.

The advantage of such a maintenance policy, however, is to always have an up-to-date equipment, unit costs can be kept at an acceptable level based on the increase in productivity.

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