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ANALYSIS AND ECONOMIC STRATEGIES REGARDING THE REDUCTION OF PREVENTIVE MAINTENANCE COSTS

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Abstract: *Maintenance represents a set of actions designed to preserve or restore a system to functional parameters. Based on the idea that maintenance is essential to production, being considered an expensive component of it, the personnel authorized for maintenance work focuses on studying and finding improved solutions and strategies for less expensive maintenance, so that they can perform maintenance works with a smaller budget compared to the previous budgets, but keeping the same quality of the services provided. These strategies are implemented in production and studied closely by the authorized persons, so that involuntary breakdowns of the machines do not occur. Once implemented, these strategies must take into account certain standards imposed by the authorized institutions in the field.*

Key words: *economic strategy, functional system, cost reduction, maintenance analysis, technology.*

1. INTRODUCTION

Maintenance is described as the totality of the operations aimed at maintaining or returning a piece of equipment to normal operating parameters. Preventive maintenance is characterized as maintenance that is carried out according to a well-established periodical maintenance plan for equipment that functions under normal conditions. These plans include both periodic inspection and verification operations, as well as replacement of parts with a certain degree of wear. The maintenance plan identifies the tasks that it must perform, as well as the intervals in which they must be carried out, calculating both the equipment's operating times and their operating cycles. Going by the idea that maintenance operations are necessary for equipment, which involve certain rather high costs, it is considered that the discovery of improved maintenance strategies and plans could shorten both the repair times and the costs related to the works, which are closely related and with the equipment's life cycle. Regarding the maintenance from an economic point of view, it starts from the approximation of the costs involved in the maintenance process, with the mention that in the event of unforeseen failures, the health of the operators is not put at risk. Previous studies have demonstrated that, by applying maintenance strategies to machinery, the costs for it are significantly reduced. These show the long-term advantages of the machines through the correct application of the maintenance strategies.

The purpose of this research is to find and implement an improved strategy of preventive maintenance, to reduce the costs of the nacelle type auto-lifting platform. The final goal is to make an improvement on the calculation models used for the work and the spare parts used for the nacelle-type auto-lifting platform, to reduce their maintenance costs. The purpose of evaluating the maintenance costs for the nacelle-type auto-lifting platform is to monitor the occurrence of defects and their remediation in the shortest possible time.

2. DESCRIPTION OF THE PROBLEM

The subject of this study was established by the challenge launched by a company that is interested in solving one of its problems regarding maintenance costs. This company operates in the field of rental of lifting equipment and has a number of 30 employees. They came to the conclusion that the maintenance department needs a large budget for the work done on the equipment

in the endowment, compared to the company's income which is based exclusively on the rental of the lifting equipment. From the calculations made by them, the costs of the maintenance department amount to approximately 65% of the budget allocated to the entire company, for a period of one year, and the profit from rentals is approximately 30%. The costs of the maintenance operations include both the operation of the entire maintenance department, which includes the cost of labor, the costs related to any subcontractors, as well as the cost of spare parts, consumables (lubricants, vaseline, etc.), the cost of transporting spare parts, etc. The maintenance department in this company is made up of 9 employees who are paid by the hour. Going by the idea that maintenance operations are necessary for machines, which also involve high costs, it is considered that finding improved maintenance strategies could shorten both the repair times and the costs related to the works, without affecting the quality of the performed operations.

3. APLICATION DOMAIN

In the industry, maintenance has a multitude of application fields. When preventive maintenance is implemented in a proper way, the equipment is maintained through a routine process, having a constant maintenance, so that they work in optimal conditions at any given moment. When the equipment works in optimal conditions, they work more efficiently and use less energy and resources, resulting in lower resource and maintenance costs, as well as an improvement in the environment. Viewed from an economic point of view, maintenance is based on the approximation of the costs involved in this process, emphasizing the fact that, if defects occur during operation, the integrity of the workers will not suffer [6]. Thus, if we take into account the calculations related to the costs necessary to implement the maintenance, the company will have a long-term decrease in the maintenance costs on the machines. Maintenance has several attributions and responsibilities considered priority in the industry, presented in figure 1. In order to preserve the production potential of the industry, maintenance focuses on the following actions: ▪ Continuous checking of the technical conditions of equipment and installations; ▪Elimination of defects that have occurred; ▪Restoring the equipment in optimal working parameters, in which they have suffered damages.

Fig. 1. Attributions and responsibilities of maintenance

The technical infrastructure includes all the company's essential elements, and their absence would cause the inability to function (electrical installations, pressure installations, water installations, air installations, etc.) [4].

In this way, the following are the responsibility of the maintenance: ▪ Quality and quantity control regarding the elements that are transported (water, compressed air, gas and similar); ▪ Replacement of degraded utility installations with new ones; ▪ Reductions of consumers, etc.

Environmental protection is characterized by all the regulations and actions that aim to reduce pollution and improve environmental conditions, where this is possible. In this case, the maintenance has the following tasks to be covered: ▪ Checking the level of NOxes and their inclusion, within the imposed limits; ▪ Diagnostics of the equipment and their condition with regard to the pollution emitted by them, etc.

Safety at work is made up of a number of laws and decisions aimed at checking machines so that they can be operated safely. In this context, maintenance must perform the following tasks:

- Carrying out certain studies to ensure the security in the operations of the machines;
- To ensure visual maintenance of

Equipment to prevent possible accidents;

- Drafting of certain internal rules for safety at work for modernized equipment, etc [1].

Maintenance, like any other elements that maintains the proper functioning of machinery, is based on several maintenance systems.

The systems that preventive maintenance is based on are represented in figure 2.

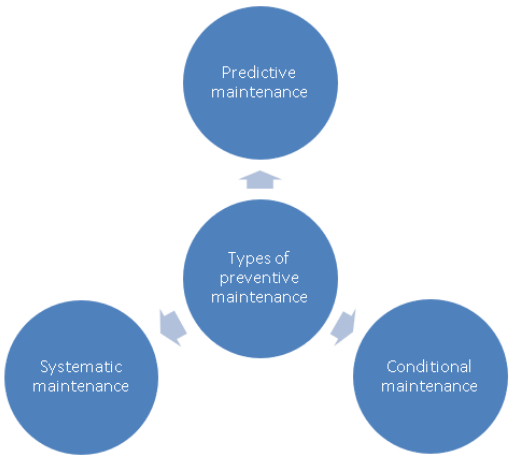

Fig. 2. Preventive maintenance systems

Anticipatory maintenance is the branch of preventive maintenance that analyzes the evolution of equipment parameters, the speed with which their components deteriorate. If an equipment breaks down, predictive maintenance can allow the delay and planning of interventions [7]. Systematic maintenance is characterized as being the help of maintenance activities, revisions, small repairs or major repairs that are found in a technical plan, which is unique for each machine. The branch of preventive maintenance, which has as its main characteristic the analysis of some essential system parameters, is called conditional maintenance. This is done with the help of special equipment called analyzers (oil, vibration, etc.). Depending on the results of these parameters, maintenance can be carried out before the appearance of the defect [9]. In terms of the complexity of preventive maintenance, it is classified as follows:

- Level 1 maintenance activities – this level of maintenance includes simple tasks that can be carried out by the machine operators. These operations are carried out daily and have as their main objectives the following: maintaining order and cleanliness at the workbench, checking the fluids of the machines used, greasing certain parts of the machines in plain view, preventive maintenance activities with reduced difficulty, making the operation sheets of the machines, etc [5].
- Level 2 maintenance activities – it includes activities with a higher degree of difficulty that can be carried out by the company`s qualified staff. These activities can be diversified according to the need of each machine, as follows: in the event of equipment failure, corrective maintenance will be applied, performing p reventive maintenance activities with a high degree of difficulty, checks of the electrical systems of the equipment, mounting or relocation of certain equipment, etc.
- Level 3 maintenance activities – these activities are carried out by the authorized personnel of the equipment manufacturing companies, third parties or expert persons other than the maintenance department, because these maintenance activities are of a high degree of difficulty and have a low repeatability [2].

4. RESEARCH STAGES

The research carried out will be structured on several stages, as follows:

- Price research regarding both labor and spare parts;
- The need for a large number of maintenance specialists, given the fact that the company is a small one;
- Elimination of additional costs from maintenance operations;
- Reduction of material and labor costs;
- Determining the level of complexity of maintenance;
- Maintenance strategies.

5. METHODS USED

In order to improve the company's income, we will use the following methods:

- Creation of stocks for frequently replaced materials and parts. Taking into account the speed with which the prices for materials and parts increase, we can create a statistic to observe the materials and parts most used in equipment maintenance, in order to create a reserve stock. So, if the price of materials and spare parts increases, the company will have parts and materials in stock for a period of time;

- Selection of suppliers of its raw materials. By requesting offers from several suppliers, we can choose the best option for us, in terms of quality / price [8].
- Subcontracting to third parties at a price lower than the worker's hourly salary. Through this method, the labor price can drop considerably, and the authorized maintenance personnel can use the extra time left free, to be able to find improved maintenance strategies;
- The increase in the rental price of machines by at least 10%. Thus, we ensure an additional income that we can redirect to the departments;
- Attribution of a minim 10% of the total repair costs to the beneficiaries. Thus, if defects occur during the rental, the beneficiaries undertake to pay for the material damage caused. With this method, we recover part of the investment in materials and spare parts [3].

6. RESULTS

In order to implement the methods of reducing maintenance costs, we will use the rental sheets, the maintenance sheets and the sheets with the parts purchased for the company's equipment for the last 6 months. After the analysis of these sheets, graphs will be created to be able to observe the ratio between costs and profit.

Based on the conclusions, we will be able to know if the proposed methods will have the expected effect or if other methods will be needed to satisfy the client's requirements so that he is satisfied. The equipment in question is a nacelle-type auto-lifting platform of the JLG 2632 ES type nacelle, represented in figure 3.

Fig. 3. Nacelle-type auto-lifting platform

The nacelle-type auto-lifting platform has been rented for the last 6 months, with a 10-hour/day operation, as follows:

- 1 week break, during which preventive maintenance was carried out;
- Rental for 3 weeks, during which the nacelle-type auto-lifting platform was rented for 20 €/h;
- 1 week break, during which the inspection of the platform and the remediation of the defects that occurred were ensured;
- Rent for 5 weeks. During this time, the platform was rented at a cost of 18 €/h;
- 2 weeks of break, during which preventive maintenance was carried out on the elements of the nacelle-type auto-lifting platform;
- In the following 4 weeks, the platform was rented for 19 €/h;
- 1 week break, during which the platform was subjected to a careful inspection and the remedy of any defects;
- 6 weeks the nacelle-type auto-lifting platform was offered to the lessor for 17.5 €/h;
- 1 week break, during which preventive maintenance was carried out;
- Rental during 2 weeks, during which the platform was rented for 22 €/h;
- One week break, during which the platform was prepared for the next rental.

Based on the conclusions, we will be able to know whether the proposed methods will have the expected effect or whether other methods will be needed to satisfy the client's requirements:

a) Before the first rental, the nacelle-type auto-lifting platform was subjected to preventive maintenance. In order to carry out the preventive maintenance, it took 3 people who worked for 30 hours each, at a price of 12 €/h. For this intervention, the following spare parts were needed: hydraulic oil (115 €), oil filter (50 €), orange paint (230 €), cream paint (170 €), stickers (60 €), wheel gear pinions (580 €), sliding roller system (260 €). The cost of the labor and spare parts is presented in table 1, case *a).*

The realized income is the total of the earnings related to the first rental, represented in equation (1).

$$15 \text{ days} \times 10 \text{ h/day} \times 22 \text{ €/h} = 3.300 \text{ €} \quad (1)$$

The profit is represented as the difference between the income and the amount of spare parts and labor, presented in equation (2).

3.300 – (1.465 – 1.080) = 755 € (2)

Figure 1, shows the report of the calculations performed for the first rental of the nacelle-type auto-lifting platform.

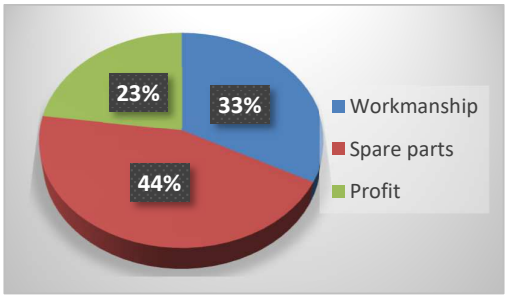

Fig. 1. Rental cost / profit ratio 1 – *case a)*

Table 1

Labor costs and spare parts for the first maintenance

Maintenance costs	Calculus	Total cost (€)
Case a) First rental		
Workmanship	3 workers x 30 h x 12 €/h	1.080
Spare parts	115+50+230+170+60+580+260	1.465
Case b) The second rental		
Workmanship	2 workers x 18 h x 12 €/h	432
Spare parts	30 + 53 + 250 + 175 + 500 + 745 + 230	1.983
Case c) The third rental		
Workmanship	2 workers x 25 h x 15 €/h	750
Spare parts	200 + 375 + 200 + 180 + 55 + 130 + 70 + 145	1.355
Case d) The fourth rental		
Workmanship	3 workers x 28 h x 16.5 €/h	1.386
Spare parts	550 + 180 + 580	1.310
Case e) The fifth rental		
Workmanship	2 workers x 16 h x 16 €/h	512
Spare parts	210 + 63 + 275 + 380 = 928 €	928

b) Before the second rental, the nacelle-type auto-lifting platform was subjected to a detailed inspection, in which defects were found that were fixed. To carry out this maintenance, it took 2 people who worked for 18 h, at a price of 12 €/h. The spare parts used for this intervention are the following: brake cable support (30 €), lifting mechanism cable protection (53 €), orange paint (250 €), cream paint (175 €), upper grills (500 €), running wheels (745 €), load sensor (230 €). The total labor and spare parts costs are shown in table 1, case *b)*. The income generated from this rental is presented in relation (3).

25 days x 10 h/day x 18 €/h = 4.500 € (3)

The profit made from the rental of the nacelle-type auto-lifting platform is presented in relation (4).

4.500 – (432 + 1.933) = 2.085 € (4)

Figure 2, shows the report of the calculations performed for the second rental of the nacelle-type auto-lifting platform.

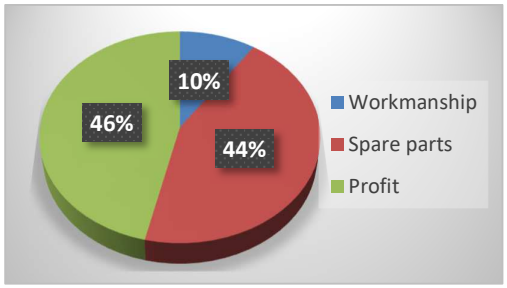

Fig. 2. Rental cost / profit ratio 2 – *case b)*

c) For the third rental, at the nacelle-type auto-lifting platform, the labor of the work is made up of 2 workers who worked for 25 hours, at a price of 15 €/h. The cost of the spare parts for this maintenance were as follows: undercarriage wheel (200 €), lower track (375 €), cream paint (200 €), lift limit sensor (180 €), hydraulic oil (130 €), oil filter (55 €), stickers (70 €), forward-backward sensor (145 €). The total labor and spare parts costs for the third rental are shown in table 1, case *c)*.

The income realized after this rental is presented in the relation (5).

20 days x 10 h x 19 €/h = 3.800 € (5)

The profit made after the rental is shown in the relationship (6):

3.800 – (750 + 1.355) = 1.695 € (6)

Figure 3, shows the report of the calculations performed for the third rental of the nacelle-type auto-lifting platform.

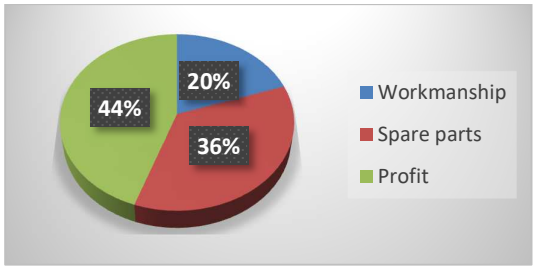

Fig. 3. Rental cost / profit ratio 3 – *case c)*

d) Before the fourth rental, the nacelle-auto lifting platform was subjected to revision, where 3 people worked, 28 hours each, at a price of 16.5 €/h. The spare parts related to revision number 4 are the following: upper grilles (550 €), overload limit sensor (180 €), ground machine control module (580 €). The cost of labor and spare parts is represented in table 1, case *d).*

The income achieved after this rental is described in equation (7).

$$30 \text{ days} \times 10 \text{ h/day} \times 17.5 \text{ €/h} = 5.250 \text{ €} \quad (7)$$

The profit made after this rental is presented in equation (8).

$$5.250 - (1.386 + 1.310) = 2.544 \text{ €} \quad (8)$$

Figure 4, shows the report of the calculations performed for the third rental of the nacelle-type auto-lifting platform.

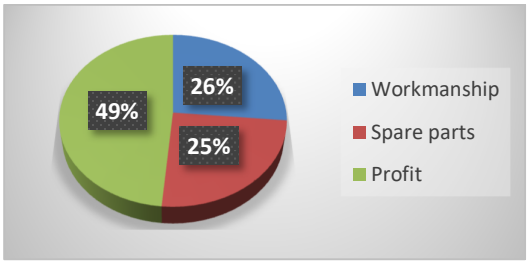

Fig. 4. Rental cost / profit ratio 4 – *case d)*

e) For the fifth rental, the nacelle-type auto-lifting platform had an overhaul in which 2 people participated for 16 hours, at a cost of 16 €/h. The spare parts for this revision were: hydraulic oil (210 €), oil filter (63 €), charge level indicator (275 €), platform extension (380 €).

The total cost of the labor and spare parts is shown in table 1, case *e).* The income obtained from this rental can be found in the relation (9).

$$10 \text{ days} \times 10 \text{ hours} \times 22 \text{ €/h} = 2.200 \text{ €} \quad (9)$$

The profit after this rental is shown in relation (10).

$$2.200 - (512 + 928) = 760 \text{ €} \quad (10)$$

Figure 5, shows the report of the calculations performed for the third rental of the nacelle-type auto-lifting platform.

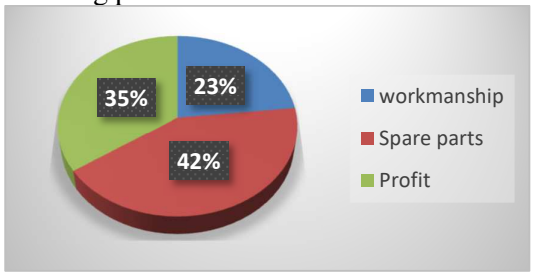

Fig. 5. Rental cost / profit ratio 5 – *case e)*

f) The total cost of labor and spare parts for the 6 months in which the nacelle-type auto-lifting platform was rented to different beneficiaries, is presented in table 2.

Table 2

Total costs of labor and spare parts for 6 months of maintenance

Total maintenance costs	Calculus	Total cost (€)
Workmanship	1.080+432+750+1.386 +512	4.160
Spare parts	1.465+1.983+1.355+1.310 +928	7.041

The income from these rentals is represented in relation 11.

$$3.300 + 4.500 + 1.695 + 5.250 + 2.200 = 16.945 \text{ €} \quad (11)$$

The profit made by the company following the rental of the nacelle-type auto-lifting platform is presented in relation (12).

Figure 6 shows the report of the calculations performed for the third rental of the nacelle-type auto-lifting platform.

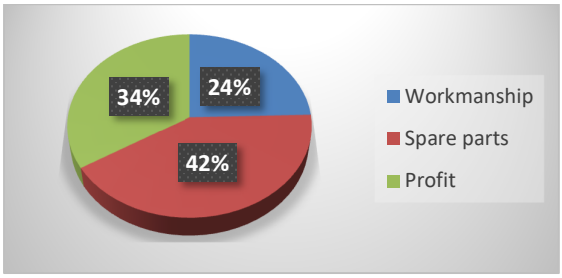

Fig. 6. Cost ratio / total rental profit / 6 months nacelle type auto-lifting platform – Total case

7. INTERPRETATION OF RESULTS

The company made a profit of 5.744 € in the last 6 months, during which it rented the nacelle-type auto-lifting platform. Judging by the fact that the company has 15 nacelle type auto-lifting platform and if they were all rented according to the previously mentioned example, the profit would increase significantly.

After a thorough analysis of figure 1, 2, 3, 4, 5 and 6, we found the following aspects:

a.) Depending on the number of hours and the price per hour, on average labor represents approximately 24% of the cost / profit ratio.

Depending on the degree of difficulty of the tasks, the labor can oscillate between 10% and 33% of the cost / profit ratio.

According to the number of spare parts, and according to their importance, the average costs regarding their acquisition represent approximately 42% of the cost / profit ratio. The cost of spare parts varies between 25% and 44% depending on the need and the purchase cost.

a) Average profit for each rental a nacelle-type auto-lifting platform is approximately 34%. Depending on the labor and spare parts costs, the profit can range between 23% and 49%.

According to the previously obtained results, we found the following changes: the price for the cream paint increased by approximately 18%, the orange paint by approximately 10%, the undercarriage wheels increased by approximately 10%, the price of the hydraulic oil increased by approximately 82%, the oil filter ended up costing 13% more, and the upper grills 10% more. For smaller and more common parts, the price increased between 5% and 35%.

8. METHODS OF INCREASING PROFIT

As proposed methods to reduce the costs of maintenance operations in terms of labor, spare parts, and implicitly increasing the company's profit, we have drawn some improved ideas, intended to help the long-term budget for the maintenance department. These ideas are based on the calculations for the last 6 months' equipment rental. From the methods mentioned in point 5, the following aspects were outlined:

a) Regarding the creation of stocks of frequently used materials and spare parts, their increase in a period of 6 months is approximately 15%. In the present case, over the course of 6 months, the costs regarding spare parts were approximately 1.000 € lower.

b) For the purchased raw materials, there is the possibility to ask for offers from several companies, where we can choose a better price in terms of quality / price. The suppliers do not have big price differences, but given the fact that the company has a continuous flow regarding the supply of raw materials, in the last 6 months the costs of the materials could be reduced by approximately 500 €.

Regarding the creation of stocks, for raw materials prices increased by approximately 10%. If stocks are created for a period of 6 months, prices regarding raw materials can decrease by approximately 350 €.

c) Subcontracting to third parties is a viable option when the price requested by third parties is lower than the price requested by the maintenance team, with the mention that the works are of the same quality. Thus, if the price requested by third parties is a maximum of 12 €/h, then in the 6 months in which the nacelle-type auto-lifting platform was rented, maintenance from the point of view of labor would have decreased by at least 650 €.

d) In order to be able to supplement the company's income, and implicitly increase the profit, increasing the rental prices by approximately 10% is a good solution. In this way, the company would have an additional profit of approximately 1.000 € in 6 months.

e) Another viable solution for increasing revenues are the imputation of at least 10% of the total repair costs to the beneficiary, in the context in which he was the one who used the nacelle-type auto-lifting platform, and the defects were also caused by the beneficiary.

In this way, the company's income for the last 6 months would have increased by approximately 720 €. If the company is willing to adopt the methods presented, it will have a profit of approximately 2.700 € higher than the existing one. Thus, the budget allocated to maintenance works will decrease by approximately 15%.

9. FUTURE RESEARCH DIRECTIONS

As future research directions, we received a challenge to optimize costs in terms of preventive maintenance, until we can reach a budget for the maintenance department of a maximum of 40% of the budget allocated to the entire company, and the profit to increase by 5% compared to from the current one.

10. CONCLUSIONS

In conclusion, it can be considered that the maintenance carried out in accordance with the expenses incurred by the company, has a quick amortization, in terms of the revenues achieved.

These are directly proportional to the costs incurred for performing preventive maintenance. Maintenance costs refer both to the materials and parts used and to the labor cost.

Taking into account the results obtained, which support the performance of maintenance at predetermined time intervals, we can say that nacelle-type auto-lifting platform will have a longer lifespan and will work in optimal parameters for a longer time, so that it will generate higher incomes for the company and implicitly, profit.

If the recommendations made are taken into account, the maintenance costs of the nacelle-type auto-lifting platform will be constant or will decrease by a small percentage.

These improvements tend to reduce the failure rate of the nacelle-type auto-lifting platform.

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ANALIZA ȘI STRATEGII ECONOMICE PRIVIND REDUCEREA COSTURILOR MENTENANȚEI PREVENTIVE

Mentenanța reprezintă un ansamblu de acțiuni menite să păstreze sau să readucă un sistem în parametri funcționali. Mergând pe ideea că mentenanța este nelipsită din producție, fiind considerată și o componentă scumpă a acesteia, personalul autorizat la lucrările de mentenanță se axează pe studierea și găsirea de noi soluții și strategii de mentenanță mai puțin costisitoare, astfel încât să execute lucrările de întreținere cu un buget mai mic față de bugetele anterioare, dar păstrând aceeași calitate a serviciilor prestate. Aceste strategii sunt implementate în producție și studiate îndeaproape de către persoanele autorizate, astfel încat să nu apară defecțiuni involuntare ale utilajelor. Strategiile propuse pentru efectuarea operațiilor de mentenanță trebuie să țină cont de anumite standarde impuse de către instituțiile autorizate în domeniu.

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