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SUSTAINABLE BUDGETING OF MAINTENANCE ACTIVITIES USING TECHNICAL INDICATORS

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Abstract: *The research presented in this paper is materialized by applying a method for maintenance activity that takes into account the technical efficiency indicators of the equipment. The control of the maintenance expenses to be budgeted is enabled by the adaptive character of these indicators which characterize the path of the previous productive process of the equipment. This paper analyzes – as a case study – the effects of using the budgeting method based on assets technical indicators and the price-per-product reporting index (between the past and present period for one year). The method is applied for the maintenance works needed to keep in good operation condition a concrete pipe pushing machine run by the company SC SOPMET SA. It is demonstrated that the application of this adaptive method to budget formulation stabilizes significantly the expenses level in maintenance activity.*

Key words: *budget based on technical indicators, safety margins, budgetary responsibilities.*

1. INTRODUCTION

Nowadays, technological processes reveal their weak points in the conditions of annual evaluation/increase of maintenance costs for the equipment used in manufacturing processes. These weak points are also detectable in the context of the continuous development of technology, consumer demands and environmental taxes imposed by law. Thus, great emphasis is placed on establishing a flexible budgeting for maintenance activity, in order to keep the production asset in normal condition as this asset is expensive, complex and has a fixed-term warranty.

Carrying out a productive economic activity involves simultaneous use of human, material and value resources, necessary for producing the goods demanded by the market.

All these constituents generate expenses under different forms and sizes: using up the workforce, consumption of materials, energy and water, depreciation of equipment etc. Part of these expenses are included in the maintenance activity, which is the weak link in the operating period of the equipment.

The maintenance costs contain also the lost opportunities during the equipment lifespan (low efficiency operation, downtime etc.) that will have a negative impact on the operational safety, the quality and price of the finished product, the safety of the personnel, the environment, the operating costs etc.

The analyzed studies highlight the significant modifications in maintenance activity with an increased focus on diminishing the number of interventions and on using eco-friendly materials, in line with the global concerns related to the climate change.

In a continuously changing environment, the greater interest for a viable and eco-economic technological process leads to a strategic analysis of the expenditures necessary for a sustainable future.

Currently, maintenance activity must be correlated with the new challenges entailed by a rapid technological evolution, the financial resources volatilization (repeated inflation) and a market with more and more expensive materials located at a considerable distance from the production area. If these materials are purchased and stored in the production area, they can become expensive due to the regional/local environmental taxes. The future of the maintenance activity seems closely related to advanced technologies and clear budgetary analyses with sustainable solutions.

Thanks to the innovations in remote interventions, the use of ecological materials and green intervention technologies, the maintenance activity has the potential to become an example of intelligent and responsible employment of the production asset. At the same time, one must take into consideration the fact that training courses are necessary for the maintenance personnel dealing with the complex production assets purchased. Due to digitalization, the production processes and maintenance activity will play an important role in the sustainability of the production flow and final product [5].

To ensure consistent budgeting with low costs, it is important to approach effectively the cost management, involving a deep understanding of the concept of

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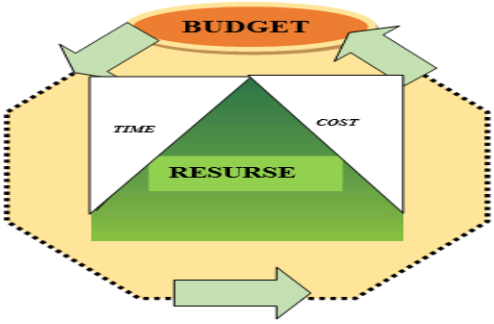

Fig. 1. Overview of coherent budgeting.

maintenance activity budget. This is defined as a complex process of planning, organization, coordination and control of resources for achieving the maintenance activity objectives, with an emphasis on meeting cost and time parameters. A graphic representation, (Fig.1), related to these definitions, highlights that an efficient maintenance activity aims to fulfill the shareholder requirements and to keep the product on the market.

Using sustainable technologies in maintenance activity and analytical instrumentation integrated into work systems will keep costs at low budget quotas/levels. The technological process will comply with the environmental and safety regulations established by the European Union, thus increasing eligibility for subsidized loans and financial incentives which will help the economic entity to withstand the market [1].

2. COST OF MAINTENANCE ACTIVITY

The cost for the maintenance of manufacturing line equipment is based on the important functions/operations to be performed. This cost is a generalizing synthetic indicator and represents the basic component of the budget. The current procedure of presenting the budget (so that to highlight expenses per major functions of finished product achievement) led to a limitation in understanding the efficient allocation of material and human resources. [1].

The management of the productive asset maintenance budget was updated by introducing *expense goals* and an analysis on prioritizing the immediate solutions to a need for additional cost. This method of the *Functional Budget* has the effect of losing the objective, namely the budgetary policy efficiency, because the method is based more on the cost quantitative analysis and less on the results quality.

The method is based more on a history of costs during the previous years, on the intensity of assets using (number of work shifts), and on the age of the asset in relation to the warranty issued by the manufacturer, thus prioritizing the decision to allocate the amount to be spent in the budgeted year [1]. The disadvantage of this method lies in its approach at a moment when the overhead costs of the company are affected by the instability of the cost of raw materials, utilities and environment, potentially leading to a blockage of the production flow. To make a classification of the maintenance costs, a synthetic concept is used, called overall cost, which represents all equipment costs over its entire life cycle.

Overall cost is formed of the followings:

a) *direct cost* – cost immediately related to carrying out the maintenance activity; it includes the following: labor costs, spare parts costs and subcontracting costs;

b) *opportunity cost* – it is a resource (labor, materials, equipment etc.) used in a certain way. One gives up the value that could have been obtained in order to use this value in another way (in the case of maintenance activity, this type of cost occurs when production operators perform specific works of maintenance and repairs);

c) *indirect cost* – it arises from a variety of indices and is not immediately related to maintenance activity. It is formed of: safety stock, failure to meet deadlines, loss of brand image and use for investments.

The overall cost is also a basic indicator in making the decision to purchase or replace equipment, if physically or morally worn out [1, 2].

3. CURRENT CONCEPTUAL MODELS FOR SUPPORTING A SUSTAINABLE COST

Optimizing performance in maintenance activity involves bringing back each time the productive system to its initial state. The possibility of mathematically modeling the maintainability characteristics influence on maintenance activity can be analyzed using notions of probability theory, mathematical statistics, Markov chains and fuzzy logic through which the refinement of mathematical methods was achieved. Mathematical modeling of maintenance activity allows to foresee the resources necessary for assets maintenance activity, to determine the missions and their starting up times and also to assess the good operation periods of the asset. One of the means to increase the efficiency of operating systems is the planning – through responsible budgeting (values kept under permanent control, by digitalization) – of technical revisions meant to ensure the system maintenance before failure. It is necessary to optimize the mentality that governed the maintenance activity until now, which mainly used the reactive interventions (with large budgets, request in advance for interventions etc.). Specialized literature [3, 4] highlights the integration of new methods, tested by different companies, namely: automation of maintenance operations, using information in real time (decisions are made depending on the amount of information available at that moment), and accessibility of maintenance information remotely with the possibility of operating the system.

The shareholders of economic agent demand continuous performance and profit for the activity of the company. This request is implemented by the de administrator, through a strategic plan, supported by a budgeting with tangible arguments (expected/achieved incomes and expenses periodically measurable and compared with the approved budget). Objectives and operating plans are provided for normal conditions and industrial stress conditions (surge in raw material prices, loss of orders, competitive aggression, inflation etc.). For the economic agent management, the maintenance budget is always a complex attempt to provide a covering

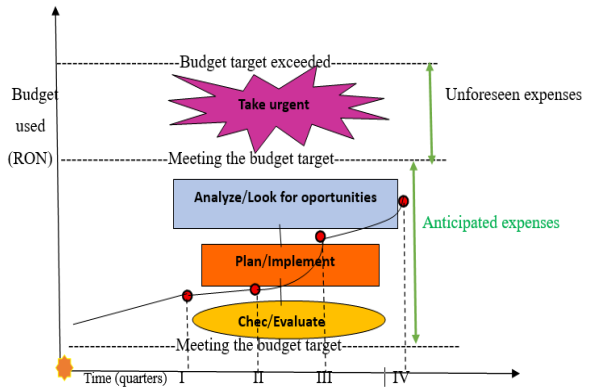

Fig. 2. Analysis budgeting.

budgeted value (forecast based on data history, technical characteristics of the industrial asset and the manufacturer's recommendations). This budget is set at an intuitive value, based on the data furnished by the operation history of the machinery /equipment. The workforce experience and the conditions stipulated in the contracts concluded with companies that manufacture spare parts or provide technical assistance are also taken into consideration [1]. One must emphasize the importance of planning the maintenance budget that supports the good operation of production assets through efficient, safe and sustainable organization. The maintenance budget is an expense assumed upon the purchase of the production asset as it is necessary for preventing interruptions and minimizing the risks of shutdowns/failures at a given time. The purpose is to fulfill the intended objectives: productivity, target costs achieved and a long-term profit, Fig. 2. The change in role and importance of maintenance activity in recent years has been determined by the following factors:

a) higher prices of the new equipment purchased, due to its constructive and functional improvement;
b) complexity of equipment through better mechanization, complex systems for movements monitoring and processes automation;
c) high costs caused by equipment damage or downtime for repairs;
d) repeated increase in maintenance costs and rise of their share in the cost products.

Besides the planning of the annual expenses at economic agent level, the maintenance expenses budgeting plays an essential role in the safety of production organization, the efficiency and productivity of work but also in the sustainability of the economic process as a whole. The carefully formulated maintenance budget reflects the commitment of the manager/administrator to ensuring the normal run of the production process, with interruptions anticipated and size of failure risks kept under control [3]. The budget must be closely related to the technical/informatics capabilities available at the time of its formulation (for example the existence of real-time monitoring systems for the state of the critical components/subassemblies /equipment). One must also take into consideration the possibilities of intervention during the scheduled shutdown periods or when there are slow production cycles, in order to generate and support a sustainable cost that does not affect the product final cost or the on-time delivery. Based on these objectives, the budgeting method for maintenance activity, represents a way to establish and justify expenses starting from the new budget year and not from the value of the expenses in the previous year history [1].

The research paper uses data generale data provided by an economic operator – SC SOPMET SA. The aim is to generate a budgeted line by implementing new idea concerning the amounts needed to maintenance activity for concrete pipes manufacturing equipment and the technological process of road underpasses. For maintenance activity, it is proposed to apply budgeting method that will take into account the technical efficiency indicators of the equipment.

This is a method that takes into account the following technical indicators of the equipment when establishing the annual budgeting for maintenance activities:

e) frequency of fault occurrence F, as a function of average uptime of the asset;
f) the severity of the fault G, is expressed by the average repair time;
g) detectability of the fault (D), namely the possibility to identify the cause of fault;
h) possibility of supporting the maintenance activity budget by the additional quantity of products manufactured and sold.

It is mention that these indicators are related to critical components of the production asset. Using this method in maintenance activity budgeting is an adaptation of the economic entity resources to current production techniques and to digitalization of the economic information/results.

4. ANALYSIS BASED ON THE TECHNICAL INDICATORS OF THE ASSET, FOR BUDGETING MAINTENANCE ACTIVITIES

The argument for using multi - criteria method based on technical indicators for maintenance activity budgeting, is the establishment and justification of future expenses, starting from the number of faults occurring during a normal operating time of the equipment (about 1000 h) and not from the expense values listed in the history of the previous year. The expenses necessary for the production asset operation will be adjusted corresponding to needs throughout the following calendar year. Establishing technical indicators of asset good functioning through the AMDEC (analysis of failure modes, their effects and their criticality) method, has the advantage of flexibility of decisions across the production process. Needless costs are avoided (coverage ensured by forecasted values). Thus, we can capitalize on our own decisions/initiatives, with sustainable costs, for achieving the main objective of the company. This objective is keeping the company on the good path, with valuable commercial results. The variant of analyzing the expenses by supporting more harmoniously the maintenance has the advantage of reducing the consumption of spare parts (stored ones) and blocking some incomes of the economic agent. The explanation of how to assume responsibly and rationally annual maintenance expenses is based on the analysis of the two ways of formulating the budget. There is the classic

Table 1

Budgetary responsibility

No.	Classic budgeting	Budgeting based on technical indicators (I_T)
1	Analysis of the previous budget	Clarity when recording expenses
2	Inflated previous expenses	Orientation towards sustainable decisions
3	Cost analysis by importance levels	Permanent argumentation of expenses
4	Forecast-based prognosis	Support based on real-time analysis
5	Analyses based on previous cases	History and requirements at recommended technical period
6	Minimizing maintenance operations clarity	Operational clarity, cost monitoring
7	Cost with low justification	Cost justified in terms of value and technical aspect
8	Repetitive operations	Turning into good account the team

budgeting way and then the budgeting based on technical indicators (I_T), which were established during the research (fault severity, fault detectability, fault occurrence frequency), Table 1.

Technical indicators-based budgeting (I_T) allows costs to be aligned to the solution that generates profit, is consistent with the requirements and does not block amounts of money based on forecasts or budget history. Expenses are included in a database that is constantly updated, making it possible to direct amounts of money from this budget line towards priority activities of the economic agent. This type of justification of budget creation represents a path to making the business more efficient. It brings the argument of identifying expenses that may become excessive and directing available sums to urgent uses, according to shareholder requirements [9].

The current practice used by the Romanian SC SOPMET SA company to support the budget line for maintenance expenses is the classic budgeting, based on the history of the operating expenses. Analyzing the steps taken to anticipate the maintenance budget value revealed the following: the company's preferred approach is to monitor expenses for operating the equipment, with the emphasis on the accounting side – how much they costs. Currently, the target is to examine the maintenance expenses; communication is made from the department head to the Accounting Department and manager; the method of preparing the budget for maintenance is based on extrapolating the data from previous year, updated with inflation, rate of exchange, etc. [4].

The research paper starts from the concept of flexibility in building the budget general through the perspective of the productive asset maintenance expenses and focusing on the functionality of profitable activity. To create the path for analysis and operation of the budget based on technical indicators, the following arguments are used: the *emphasis* is on decision; the *approach to the money amount necessary for maintenance* depends on the objectives achievement; the *target* is the cost-benefit; the *communication* of needs

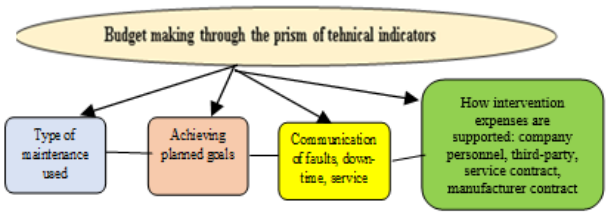

Fig. 3. Defining elements of budgeting.

will be made from the bottom up, from the top down and between compartments; the approach will be continuous, with cost, benefit and risk as analysis elements, Fig. 3.

The maintenance cost analysis pattern taken into consideration in this research paper is based on several working ideas of the authors. Thus, before saying that an intervention cannot be solved with the forecasted costs, an attempt is made to find work options that can solve the situation with reasonable costs. Positive changes are used at once; efficient technical solutions are introduced immediately, without expecting too long the perfect solution in terms of technology and value. One tries to turn the encountered difficulties into efficient solutions; the argument *sunk cost* is avoided. The practice of maintenance activity highlights that de the budget target of the costs for maintaining a production asset in operating conditions involves an annual expenditure of 8-10% at the most of the acquisition value. This target can only be reached with the substantial support from the part of the technical and economic departments.

5. CASE STUDY

In a society focused on production, monitoring the variation of unit prices per product constitutes – in the current international context - both a means and an end at the same time. It is a means because prices per product represent a measurable result of the production activity as they are able to best reflect the economic activity of the company. Monitoring is an end, because a pricing policy is always put at the forefront of the concerns related to improving the economic situation of the company or keeping it at the same level [3, 8].

5.1. Sustainable pricing policy

Adopting a formula for analyzing the movement of the prices per product/work is a matter that can be treated scientifically in terms of budgetary indicators.

These indicators reflect the variation in the cost of a product/work. In other words, are the key to creating the variation index of the requirements for achieving product/work. Quantities of components and service operations to be consumed can be set through the budget, denoted by q_1, q_2, q_n and their price denoted by p_1, p_2, p_n.

In the first year, these ones will have a value in the budget, denoted by S_0, respectively:

$$S_0 = q_1 \cdot p_1 + q_2 \cdot p_2 + .. + q_n \cdot p_n = \sum q_n p_n. \quad (1)$$

The following year, if the quantities are the same, but the fiscal policy is different, additional expenses arise with maintenance activity and taxation of the resulting

waste (p_m), which leads to an increasing budget and a value S_1, respectively:

$$S_1 = q_1 \cdot p_1 + q_2 \cdot p_2 + .. + q_n \cdot p_m = \sum q_n p_m. \quad (2)$$

By relating the initial year to one of the following years, it enables establish the variation index of the necessary amount to be added to the budget, as follows:

$$I_1 = \sum q_n p_m / \sum q_n p_n, \quad (3)$$

where p_n is the price year 1, p_m – price in year 2, p_M is the price at the budget variance due to adding additional costs to the maintenance activity.

In this regard, the budget variation due to the addition of additional costs for maintenance activity during the calendar year is analyzed, as follows:

$$S_2 = q_1 \cdot p_1 + q_2 \cdot p_2 + .. + q_n \cdot p_M = \sum q_n p_M, \quad (4)$$

$$I_2 = \sum q_n p_M / \sum q_n p_n. \quad (5)$$

The existence of an increasing variable budget leads to the increase of maintenance activity expenses [3].

Through sustainable management of the additional expenses (environmental taxes, increasing maintenance activity), the index value will be super unitary, within a well-established range. The condition for sustainability (analyzed in the paper) is that this index I_2, established to reflect sustainable technological development, be $I_2 \leq 1.2$ for the following year (taking into account the increase in taxes and maintenance costs of 5% of the asset value). If this value is exceeded, one considers that the general budget must also cover unforeseen costs, which could reduce the profit of the company because the budget line of the maintenance activity is over the sustainable area. In such a case, the legal possibilities for environmental taxes exemptions, the government aids to support sustainable activity, the expenses per each asset and the replacement of those assets that absorb high expenses will be analyzed.

The budgeting of maintenance activity at S.C. SOPMET S.A. begins with the expenses incurred in the previous year, to which added is he anticipation of the exchange rate for the next year. The amount that covers the expenses (inflated by the value of the previous year) is increased by the inflation rate forecasted for the following year, to which a 5% gross margin is added to the total value [6]. The research analyzes the effects of applying the budgeting method by using the asset technical indicators and the price-per-product reporting index (between the past and present period / per year). This budgeting method was used in the case of maintenance works for keeping a concrete pipe pushing machine IFO220 type in good running order. The machine operates under a road, without stopping the traffic, by the pipe-jacking method (Fig. 4) [9].

The AMDEC method (analysis of failure modes, their effects and their criticality), allows analyzing the failure mode of the aforementioned asset, based on the criticality C (critical failures) and its effects on the making of the budget for the following year.

The criticality of the defect can be expressed by the formula:

a b c

Fig. 4. Concrete pipe pushing machine; *a* – pipe; *b* – machine assembly; *c* – active block.

$$C = F \cdot G \cdot D, \quad (6)$$

where: F – frequency of occurrence, G – fault severity, D – fault detectability.

The expenses will be analyzed for 1000 h of equipment running (requirement of the company). This period will be examined per four stages of operation, namely: less than 200 h, between 300 h and 600 h, between 600 h and 1000 h, more than 1000 h. Table 2 presents the proposed way to evaluate the frequency of occurrence factor F, depending on the average time of good operation

Severity of the fault G represents the criticality of the fault and is expressed by the mean time to repair (MTR). It is possible to evaluate the G (with values sown in Table 3) based on the mean time to repair.

The fault detectability expresses the probability of determining the cause of fault occurrence. The evaluation coefficient D is shown in Table 4.

Table 2

Evaluation of the frequency of occurrence – *F*

No.	Criterion description	Evaluation coefficient *F*
1	Assets fail at an interval larger than (MTFB >1000 h)	1–2
2	Assets fail at an interval of 600 < MTBF < 1000 h	3–4
3	Assets fail at an interval of 300 < MTBF < 600 h	6–8
4	Assets fail at an interval under MTBF < 200 h	9–10

Table 3

Evaluation of the fault severity – *G*

No.	Criticality of the fault severity	Evaluation coefficient *G*
1	MTR < 1 h	1
2	MTR < 1 day	2-3
3	1 day <MTR < 2 days	4-5
4	2 days < MTR < 4 days	6-7
5	4 days < MTR < 6 days	8-9
6	Replacement of asset	10

Table 4

Evaluation of the fault detectability – *D*

No.	Criterion description	Evaluation coefficient *D*
1	Fault detected by automation	1
2	Fault detection through asset investigation	2–3
3	Fault detection at service station	4–5

The efficiency of this study lies in the possibility of to consult the faults history of the asset mentioned above (at the company maintenance department which files the problems occurred over the previous 3-year period). The study conducted on this equipment makes it possible to analyze how the failure occurred, its effects on the contracted work, and also the possibility to formulate a sustainable budget for maintenance activities in the future. The necessary information was extracted from the file containing the faults history of this equipment. The complete information about the operation of this equipment, presented in Table 5, was obtained by corroboration with the evaluation coefficients corresponding to the technical indicators (Tables 1–3).

Faults were analyzed for the following components of the equipment: housing, electric equipment, hydraulic unit, pipe.

Analyzing the data listed in Table 5 it is observed that the highest value of C is 10, for the concrete pipe; value occurs when the concrete pipes are incorrectly stored, which affects the smooth running of the works (there is a high value involved: 14.288 RON/piece, for concrete pipe). The lack of a stock of pipes implies labor for transportation, loading and unloading time, transport equipment, etc. [6, 9].

Damage to contactors, bolt wear, damage to hydraulic hoses, and damage to electrical cables are also very frequent. This information allows a careful analysis of expenses, constituting a defining step in the creation/formulation of a sustainable maintenance budget. The results of this analysis provide the technical staff with information about the value of the expenses required for the proper functioning of the equipment [8]. The value of the anticipated expenses to be included in the future budget is documented with technical reasons activity history. These expenses can be decreased or increased depending on the duration of the equipment use. The elements taken into account when analyzing the expenses included in the budget must have justification from the part of the persons in charge with each package of expenses (operator, technician, and engineer). To have a thorough analysis of the amounts spent and entered into the budget, a number of four categories of expenses are chosen [7].

They are analyzed closely in Table 6. The analysis is performed by recording the costs incurred in the first quarter of 2024. One analyzes a new variant of setting the budget for 2025 using of technical indicators. Data presented in Table 6 highlight that the use of this method is effective in budget making for the first quarter of 2025.

The objective was to decrease the budget created by the classic variant (history of expenses). The result is conclusive, as the budget for 2025 has been substantially reduced. From the analysis of the recorded data, a

Table5

Determining *C*

Subassembly	Main faults	Main causes	Main effects	*F*	*G*	*D*	*C*
Equipment housin	Guideway faults	Friction wear	Low force when	1	2	2	4
	Fault of eye bolt	Housing wear	Vibrations possibility	1	1	2	2
	Bolt wear	Friction wear	Low force	1	2	2	4
Electric equipment	Powern panel connec tors	Weathered electrical panel	Machine shutdown	4	1	2	8
	Damaged cables	Exposure in traffic areas	Machine shutdown	1	2	2	4
Hydraulic unit	Oil leaks at the pistons	Worn gaskets	Low pushing force	1	2	2	4
	Leaks in the hose routing	Damaged hose	Low pushing force	1	2	2	4
Concrete pipe	Cracked	Improper storage	Breakage	1	5	2	10

Table 6

Valorization of data about budgetary expenses of maintenance

No.	Expense groups	Classic budget achieved 1st quarter 2024	Budget basedon indicators 1st quarter 2025	Results RON	Percent %	Costs justification
1	Expenses for repairs parts	26.832	20.897	5.935	22,1	Spare parts repairs of components
2	Other services for operation	6.600	5.923	677	10,2	Arrangements forequipment and machines, area security
3	Supplies	6.124	6.047	77	1,2	Oils gaskets protection bellows signaling lights
4	Service	4.000	4.000	0	-	Service contract – quarterly payment
Total		43.556	36.867	6.689	/	----------

Note: - The National Bank of Romania published a reference exchange rate of 4.97310 RON for one Euro on 03.01.2024 [12];
- The National Bank of Romania published a reference exchange rate of 4.97700 lei for one Euro on 23.03.2025 [12].

decrease in costs per each group is observed se as a result of using this method in the context of an inflation rate of 5.4% in 2024, and an inflation rate of 7%, in the first quarter of 2025 (according to INS). The exchange rate of the national currency recorded a slight increase at the beginning of 2025 compared to 2024 [10].

Analyzing the data presented Table 6, oen can highlight that the zero-based budgeting, using technical indicators, represents an evolutionary approach in the creation of the budget for maintenance activity. By improving the expense analysis system with the help of algorithms, the operating expenses of an economic entity will be sustainably managed [11].

6. CONCLUSIONS

The study, developed at the level of an economic entity, puts into practice a way of compiling the maintenance budget, using the technical indicators of the asset.

This budgeting method, implemented within the company SC SOPMET SA, had a positive impact by reducing the expenses necessary for maintenance activities. A clear picture of the reduction of expenses in the production flow can be obtained if an analysis is made over a period of one year. This budgeting method using technical indicators is effective if it is applied responsibly.

The amounts remaining from the efficient management of expenses can be transferred for the economic growth of the company (used for investments, innovation, specialization of jobs, payment of taxes, etc.).

The budgeting method using technical indicators will allow the company to carefully manage its capital, maintain its prestige on the specialized market and have the courage to register in the Romanian Sustainability Code.

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