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IMPLEMENTATION OF THE MODELS OF OPERATIONAL RESEARCH FOR THE SOLUTION OF THE CNC MACHINES LIFE CYCLE

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Abstract:
Operational research is a significant part of management, based on improving efficiency, operability, and machine quality. Those improvements influence the time of the repair process, workforce availability for the repair process, safety, and environment. The main goal of this article is to investigate the optimal – operating service life of the machine and the optimal – operating time interval for the renewal of the CNC metalworking machine. The research was implemented in a small enterprise in Slovakia that needed a CNC machine in the production process. The research hypothesis was determined H1: Using quantitative models of operational research can manage the machine's life cycle. We used quantitative mathematical models of operational research. By calculation, we found that the optimal – operational lifetime of the CNC machine is 6 years. The renewal time of the machine is between the 5th and 6th year of use with a minimal level of the total costs for repairs and maintenance. This simulation is essential information for the financial plan for CNC machine renewal. The results of the research showed a confirmed hypothesis. The suggested proactive model is a viable instrument for the machine park in small enterprises with various orientations.

Key words: costs, efficiency, improvement, operational research, models

INTRODUCTION

The machine park in the small enterprises is the base production factor for the production process. Each production factor creates costs that introduce a financial burden. Using the machine park influences the financial, personal, technical, technological, environmental, and economic situations. This situation is connected to financial resources, the machine life cycles, the operability of machines during the use period, and the high maintenance costs. The main goal of this article is to investigate the optimal – operational service life of the machine and the optimal – operational time interval for the renewal of the CNC metalworking machine. This primary goal can be solved by models of operational research and their use in practice. The part of the research was Hypothesis H1: Using quantitative models of operational research can manage the machine's life cycle. Cehlar et al. [1] described in their article that solving problems of machine parks creates new possibilities for investment. One of the areas is a machine park for the production process [1]. Problems are oriented on financial resources, buying of new machines, and machine repair processes in small enterprises. This reason forces small enterprises to plan financial resources, repair processes, and maintenance, as well as to know the machine's life cycle from the view of depreciation and taxes. Che-Yahya et al. [2] presented that machine innovation is an essential strategy for competitive survival over the long term. The lack of financial support may prevent the firms from entirely pursuing innovation activity and producing innovative outputs. The results of the research presented that both financing sources (internal and external) are essential in driving the volume and value of firms' innovation outputs [2]. The combination of financial resources and effective types of models of operational research are managerial innovative instruments. Their use in practice could be better because the models are timely and mathematically demanding. Calculation of those models needs training staff and new software. Despite that, the operational research models create a way to affect the maintenance process of machines and plan the financial resources for reconstruction and modernisation. This article will use operational research models connected to a machine's life cycle to fulfil the goal.

LITERATURE REVIEW

The life cycle of machines creates the base for the Machine Park in the firms. The life cycle is an important economic indicator for modernisation, reconstruction, reparations, modifications, and innovations of machines and equipment. The life cycle is connected with operational costs and influences the financial situation of the small firm. Mecheter et al. [3] commented that life cycle assessment (LCA) and life cycle costing (LCC) are powerful methods that can be used for assessing environmental and economic performance. Their research showed that electricity consumption is the main contributor to environmental impact, and CNC technologies create 91% fewer costs than additive manufacturing [3]. One area of business and process performance is cost reduction in all processes. Liu and Zheng [4] solved the research of the CNC machine redesign with orientation to the life environment. They suggested the green performance indicator system for modules of the CNC machine tool. The application case showed that the proposed priority-order recognition method provides a scientific basis for the greening improvement of CNC machines. Those changes introduce cost reduction in the CNC machine's life cycle [4]. Potkány et al. [5] commented in their research that the selected quality management practices can ensure that the customers' needs are met and thus contribute to higher process performance. Selected practices of quality management – TQM, Kaizen, Six Sigma, and Quality controlling are the best instruments for the changes [5]. With quality management practices, small firms can increase their productivity and efficiency, reduce process variability, increase production quality, increase machine operability, and influence customer satisfaction. Machine park financing is one of the critical tasks in small enterprises. Kádárová et al. [6] said that the opportunities for enterprise financing depend on macroeconomic and microeconomic indicators. It is a process that allows the enterprise to survive or progress. The financial instrument for buying machines is investment financing. It aims to fulfil the investment needs of enterprises by spreading investments [6]. The funding of machines depends on the life cycle of machines and the phase for which we need to plan financial sources. Teplická et al. [7] presented the life cycle of machines in the article. The life cycle of machines (Figure 1) in the firms represents three primary phases.

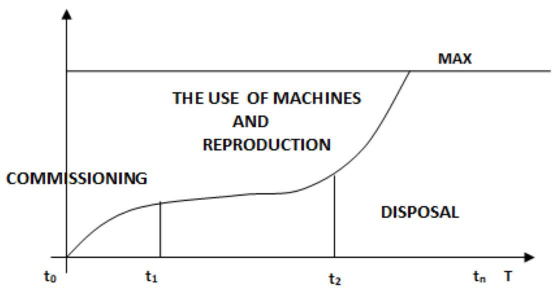

Fig. 1 The life cycle of the machine
Source: [7].

The first phase is the running-in of the machines connected with buying (commissioning), the second phase is the use of the machines and the associated machine restoration (use of machines and reproduction), and the third phase is the decommissioning of machines after the life cycle time (disposal) [7]. Bruckner et al. [8] presented future simulation trends, including simulation techniques and cloud solutions for machine life cycle plans [8]. Potkány et al. [9] said that the optimisation of the machines is related to the service life, and therefore, it is necessary to monitor the machine use during the life cycle. All the steps of the life cycle of machines depend on financial resources and influence the economic situation of the firms. Planning of the monetary reserve and sources is needed during the life cycle. All phases of the life cycle are connected with financial parameters such as procurement-related costs, quality costs, operational costs, labour costs, material costs, maintenance costs, energy costs, transport costs, depreciation, and others, that are part of the target calculation of the product [9]. The second phase of the life cycle is connected with the quality of the reproduction process. Machine reproduction has to be planned during the machine's life cycle. This process involves quality costs that must be reduced and optimised. Teplická et al. [10] presented that quality cost optimisation can be realized through managerial instruments, quantitative operational research methods, and reproduction theory methods. This theory is a scientific discipline that deals with machines and equipment that are discarded due to wear and tear [10]. The second phase – the machine's life cycle reproduction process uses optimizing models. In these renewal models, the wear and tear of the machine, its decreasing value, and the increasing costs of keeping it in a productive state are monitored. These are repairable parts in which repairs eliminate malfunctions or preventive maintenance is carried out. These mathematical and quantitative models aim to determine the optimal machine service life based on the established indicators. Buer et al. [11] commented that the supported instrument for optimised models is the Bayess principle optimization model for managerial decisions and continual improvement. The synergy of those models is a prerequisite for the efficiency and operability of machines [11].

RESEARCH METHODS

As part of the research, we proceeded based on the algorithm of steps (Figure 2), the essential tool for managing the implemented project in a small enterprise in Slovakia.

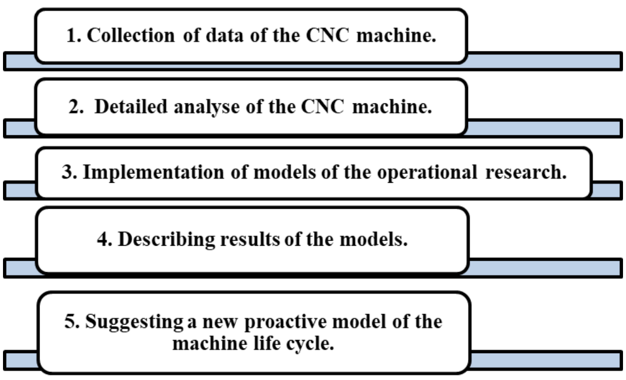

Fig. 2 Algorithm of the research

Various methods, such as mathematical models and graphical methods, were used to solve the project. We dealt with the economic life cycle of the CNC machine during its use phase. The research was implemented in a small enterprise in Slovakia that needed a CNC machine in the production process. CNC lathe Bernardo CK is a metalworking machine for small components produced in the firm. This CNC machine has an operating mode of 8 working hours per shift. The CNC machine has two machine workers with qualifications for one shift. This CNC machine has diagnostics and visual monitoring equipment. The monitoring of the machines' state is recorded every hour. The actual effectiveness of the machine is 85% because the machine does not register serious failures or any downtimes. This CNC machine is of high quality and operable. The optimisation methods of operational research were used as a simulation – prediction. It was the reason for preparing preventive measures to ensure machine operability, maintenance, and possible repairs. The complex reproduction process needs to plan financial sources in the small firm, which is why simulation is used.

Collection of data of the CNC machine

We obtained the data from the firm's production department. The detailed information was recorded on the CNC machine card. Financial information (price, costs, and depreciations) was selected from SAP modules for accounting. The coefficient of growth was 11%. This number was taken from the statistics of the internal documents in the internal database.

Detailed analysis of the CNC machine

Our research analysed the machine, CNC lathe Bernardo CK (Fig. 3), from the life cycle perspective.

Fig. 3 CNC lathe Bernardo CK

Source: internal document.

This machine is a metalworking machine designed for precisely machining engine parts such as heads and blocks.

CHARACTERISTICS OF THE MACHINE

It is a lathe with electronic manual movement in the x and z axes. The axes are equipped with servo motors and ball screws – AC motors power main drives and feed drives. The machine control is a simple version of the Siemens 808D Advanced control. Other components of the Bernardo CNC lathe: jaw chuck diameter 160, automatic six-fold head, cooling system, LED work light, rotating tip, automatic lubrication of longitudinal and transverse slides, control electronic handwheel, complete protective cover of the machine, service and service tools. Technical parameters of the CNC machine are presented in Table 1.

Table 1

Technical parameters

Type of technical parameters	Parameters	
	Number	Units
Engine output S 1100%	3700	W
Engine power S 640%	5100	W
Supply voltage	400	V
rotating diameter	360	mm
rotating diameter above the support	150	mm
spike height	180	mm
turning length	500	mm
bed width	260	mm
spindle speed	150 ÷ 2,500	[U.min^{-1}]
spindle design	A2-6"	
spindle passage	60	mm
quill stroke	100	mm
quill diameter	50	mm
pinole cone	MK4	
displacement range in the X-axis	180	mm
displacement range in the Z-axis	500	mm
rapid traverse in the X-axis	4,000	[mm.min^{-1}]
rapid feed in the Z-axis	7,000	[mm.min^{-1}]
weight	1,350	[kg]

Source: internal document.

Inputs for models of operational research

In the first step, we collected data (Tables 2, 3, 4) from the SAP database and internal documents of the selected firm in Slovakia. Including the purchase price (OC) are costs (Noc) connected with the purchase.

Table 2

Economic inputs for optimization

INPUTS	Units
(t_o) time of buying the machine	The year 2020
(OC) purchase price	21480 €
(Noc) costs connected with the purchase price	4890 €
(ω) lifetime of machine	8 years
(No) repair in 6 years of lifetime	2000 €
Nuo	5850 €
(k), (i)	11%

Table 3

Operating costs

INPUTS	Units
Np (2020)	1200€
Np (2021)	1450€
Np (2022)	1700€
Np (2023)	1950€
Np (2024)	2200€
Np (2025) plan repair 2000€	5000€
Np (2026)	5250€
Np (2027)	5500€

Table 4
Depreciation

INPUTS	Units
O1	6370€
O2	5000€
O3	5000€
O4	2000€
O5	2000€
O6	2000€
O7	2000€
O8	2000€

Source: internal documents of SAP system.

Those costs create transport costs, installation costs, and operator training costs. The CNC machine manufacturer indicates the need for more extensive repairs in the 6-year life span of the machine of €2,000. Physical wear is determined by the life of the device set by the manufacturer at 8 years. Depreciation is carried out by internal company guidelines, with a precisely defined depreciation plan.

The operating costs of the machine were €1,200 in 2020, €1,450 in 2021, €1,700 in 2022, and €1,950 in 2023. From this information, the coefficient of operating cost growth in the following period can be assumed. At the same time, the assumption of total maintenance and repair costs for the period of operation until 2027 is €5,850, with increased costs of 11%. The discount rate used in the calculations was set at i = 11% with acceptance of the energy crisis, economic crisis, and inflation. The residual price of the machine after 4 years of use was €10,000, and they used straight-line depreciation for the remaining years. Depreciation in the first year of use of the machine was determined by an internal directive, which states that depreciation is calculated by subtracting the total value of the machine from the purchase price, i.e. €20,000. The residual cost of the machine in the second and third year is calculated by dividing by 4 times evenly, i.e. €5,000, and the last years are recalculated by equal depreciation from the residual price, i.e. €2,000.

CHARACTERISTICS OF THE OPTIMIZING MODELS OF THE OPERATIONAL RESEARCH

Model of the optimal time of the reproduction

The is a cost-oriented model, the criterion of which is the target function. This function is expressed by the total costs associated with using the machines. The function is focused on the processes of physical wear and tear, eliminating the negative consequences of physical wear, and using during the life cycle (from commissioning to decommissioning). Physical wear and tear is related to its actual lifespan.

The main goal of the model

The primary goal of the model is to speed up the reproduction process. We are determining the economically advantageous time of the use of machines.

Model input parameters

(Np) – costs of operation, repairs, and maintenance expressed in (€)
(Oc) – purchase price of the company's share capital expressed in (€)
(Zc) – the residual price of the company's share capital expressed in (€)
(v) – discount factor – dimensionless number ()
(i) – interest rate – expressed in (%)
(Ot) – amount of depreciation in individual years expressed in (€)
(t) – time interval of use of fixed capital in (year, month)

Target function

The optimal value of the objective function is defined on the time interval (t). The objective function is a function of the total costs expressed by the sum of the operating costs and the costs of losses. Nc(t) = f(Np(t) + Ns(t))
Np(t) – operating costs,
Ns(t) – loss costs,
Optimization condition: f(t+1) › f(t) ‹f(t-1)
At the time (t), in which the target function f(t) acquires the minimum value is the solution of the model (Table 5) [12, 13].

Table 5
Algorithm of the model of the optimal time of the reproduction

Indicators	Mathematical calculation	Units
(Np)	*Np*	(€)
(ZC)	$Z_c = O_c - \sum O_t$	(€)
(v)	$v = \frac{1}{1+i}$	()
(v) for time (t)	$v = (\frac{1}{1+i})^t$	()
(v) for time (t-1)	$v = (\frac{1}{1+i})^{t-1}$	()
(Np_d)	$Np_d = Np_t \times v^{t-1}$	(€)
(Np_k)	$Np_k = \sum_{t=1}^{n} Np_d$	(€)
(Zc_d)	$Zc_d = Zc_t \times v^t$	(€)
f (t) - Nc	$f(t) = \frac{Oc + Np_k - Zc_d}{1 - v^t}$	(€)
Optimal reproduction time (top)	$t_{opt} = \min f(t)$	(time – year, month...)

Model of optimal lifetime

It is a cost-oriented model, the criterion of which is the target function. The reproduction of machines and production equipment is the goal of managing and caring for the machines.

The main goal of the model

The primary goal is to determine the optimal life cycle (of machines and production equipment) based on the environment in which the machines are used. It is time from the moment of its inclusion in operation to the moment of its removal from operation.

Model input parameters

(Nuo) – maintenance and repair costs,
(Zc) – the residual price of the machine,
(Oc) – purchase price of the machine,
(k) – coefficient the rate of growth of the costs.

Target function

The optimal service life determines when it is necessary to renew the primary asset in the form of repair, overhaul, purchase of a new essential asset, rental, etc. The optimal lifetime determines the marginal average cost. Lifetime optimization is based on selecting a lifetime that is the minimum function of average operating costs (Table 6) [12, 13].

$$N_{c_{opt}} = \left(\frac{O_c - Z_c}{\omega^*}\right) + (k \cdot \omega^* \cdot N_{uo}) - MIN \qquad (1)$$

Table 6

Algorithm of the model of optimal lifetime

Indicators	Mathematical calculation	Units
(N_{uo})	$N_{uo} = N_u + N_o$	(€)
(ZC)	$Z_c = O_c - \sum O_t$	(€)
(OC)	O_c	(€)
(ω)	$\omega^* = \sqrt{\frac{O_c - Z_c}{k \times N_{uo}}}$	(time – year...)
(Nc)opt	$Nc_{opt} = (\frac{O_c - Z_c}{\omega^*}) + (k \times \omega^* \times N_{uo})$	(€)

Source: [12, 13].

RESEARCH RESULTS

The research was carried out in a selected small firm in Slovakia. The main goal was to investigate the optimal service life of the machine and the optimal time interval for the renewal of the CNC metalworking machine. We used operational research models, such as a model of the optimal time of reproduction and a model of optimal lifetime. Including the research is Hypothesis **H1: Using quantitative models of operational research can manage the machine's life cycle.** This hypothesis will be investigated during calculations of the optimal models for the CNC machine. By using the models, it is necessary to find out the optimal service life and the optimal recovery time of the machine during its life cycle.

Model of the optimal time of the reproduction

In the implementation of models of operational research, we used the algorithm of the model of the optimal time of reproduction (Table 5). We used inputs from part of the article Research Methods for the calculation.

Based on the calculation of the model (Table 7), it was found that the optimal time for the restoration of the machine is between 5-6 years of its life and its use in praxis in the production process (Figure 4). In the 5th year, the purpose function acquired the minimum operating costs on level 72736 € for machine operability. This results in the firm's attention to planning financial sources for machine reproduction (modernisation, repair process, reconstruction, innovation) in 2024.

Table 7

Model of the optimal time of the reproduction

(t) / indicators	1	2	3	4	5	6	7	8
NP	1200	1450	1700	1950	2200	5000	5250	5500
ZC	20000	15000	10000	8000	6000	4000	2000	0
v	0.9009	0.8116	0.7312	0.6587	0.5935	0.5346	0.4817	0.4339
NP_d	1200	1306	1380	1426	1449	2967	2807	2649
NP_k	1200	2506	3886	5312	6761	9728	12535	15184
Z_{Cd}	18018.02	12174.34	7311.914	5269.848	3560.708	2138.563	963.3168	0
f_t	96388.18	88662,2	85354.97	77393.6	**72735.17**	72975.44	73198.64	7340803
f_{tmin} = NC	72735.17							

Legend: NP – operational cost, ZC – residual price, v – discount factor, NP_d – discount operational cost, NP_k – operational cost cumulative, Z_{Cd} – discount residual price f_t – optimise function.

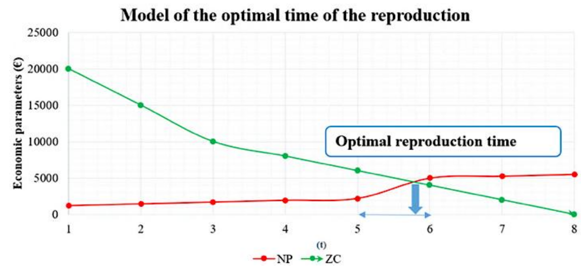

Fig. 4 Optimal reproduction time

Model of optimal lifetime

In the implementation of models of operational research, we used the algorithm of the model of optimal lifetime (Table 6). We used inputs from part of the article Research Methods for the calculation. The results of the model are presented in Table 8.

Table 8

Model of optimal lifetime

Indicators	calculation	Units
N_{uo}	5850.00	€
ZC (8 years of use)	0.00	€
OC	26370.00	€
(k)	0.11	
(ω) optimal lifetime	6.40	year
Nc_{opt}	8238.71	€

Legend: N_{uo} – maintenance and repair costs, ZC – residual price, OC – purchase price, k – growth coefficient, Nc_{opt} – optimal operating cost.

The CNC machine manufacturer indicates the need for more extensive repairs in the 6th year of its lifetime; this year, the optimal lifetime for the CNC machine was determined. The initially planned maintenance and repair costs were €5,850. However, the model determined the sum of costs in the 6th year of use at €8,239, which means an increase in costs associated with a higher failure rate. This calculation shows that starting this year, we need to plan financial sources for the higher failure rate of the CNC machine. The production lifetime is 8 years, which means the machine can be used, but we need to plan financial reserves for the reproduction process (Figure 5).

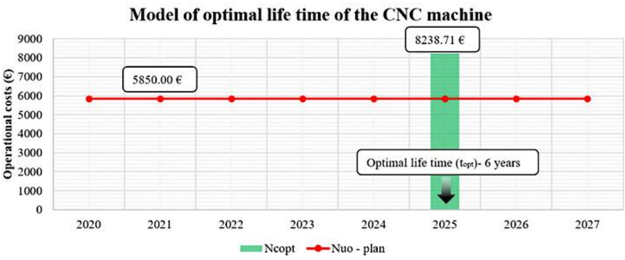

Fig. 5 Optimal lifetime

Six years of the lifetime of the CNC machine is needed to solve the crisis with the machine park, plan the reproduction process, reduce maintenance costs, and find out the financial sources for buying the next machine – investment.

DISCUSSION OF RESULTS

A total productive maintenance plan in the machine life cycle is essential to the maintenance process and machine operability. Devanda et al. [14] commented that the implication of machine repair problems is growing with the new technology for socioeconomic progression, mobility, security, and safety [14]. The main goal of the maintenance process is to investigate uncertainties and impreciseness in optimistic and pessimistic conditions of the maintenance process. Nonlinear and other operational research methods are used as bases for proactive maintenance. Koukaras et al. [15] said that proactive maintenance has recently attracted scientific attention. It integrates the advantages of descriptive and predictive analytics to automate detecting a machine's functionality. Proactive measures may improve equipment dependability and minimize operational expenses [15]. Szwarc et al. [16] showed the significance of the maintenance staff. Highly qualified staff is the key to successful operations management. Proactive maintenance must be built on planning the rotational assignment of work tasks to multi-skilled staff to guarantee they maintain their competencies at the required level [16]. Otic et al. [17] presented that the basis for proactive maintenance is the analysis of the root cause of the failure, i.e. the determination of the mechanism and cause of failure occurrence. The root causes of machine failures can be eliminated [17]. Markulík et al. [18] presented in their research the way the reproduction process of the production line, such as part of machine park optimisation, was chosen and by using the quality instrument Ishikawa diagram (Fishbone diagram) determined the particular categories of reasons and causes of failure. Those causes of the reproduction process of the production line meant costs increased. The solution was effective cost control, and it was used in the area of the machine park [18]. Ambriško et al. [19] commented that maintenance is a critical process affecting productivity and creating added value. The key indicators of the maintenance process are costs and their reduction, capacity planning – staff, material, spare parts, work utilisation, optimal material delivery, and monitoring the fulfillment of the repair plan [19]. The results presented by all authors may help prepare a proactive model, which is the primary goal of this research. The research included Hypothesis H1: Using quantitative models of operational research can manage the machine's life cycle. The results of the research showed a confirmed hypothesis (Table 9).

Table 9
Results of models

Indicators	Units
Reproduction optimal time	5 years of using
Reproduction process time	between 5-6 year
Operating costs	72 736 €
Optimal lifetime	6 years
Total costs for maintenance and repair	8 239 €

Using a quantitative operational research model, we fulfil the primary goal of the CNC machine life cycle maintenance process. We know information about reproduction optimal time, process time, opretating costs, optimal lifetime and total costs from the maintenance process and repair process for CNC machines. The research results create possibilities for a plan of financial resources for the reproduction process, and the management can solve the type of reproduction of CNC machines. Potkány et al. [20] solved cost reduction in business processes. Cost reduction is a base for using outsourcing principles. Outsourcing is primarily used as a strategic tool for corporate resource optimization [20]. In their research, a general model for an economic efficiency evaluation was proposed for the potential use of outsourcing. This approach is one of the solutions for the reproduction process in small firms' machine parks. By outsourcing, small firms can reduce the operational costs of machines. Ivanová et al. [21] presented that energy costs are the highest category of costs in the production processes. They dealt with energy consumption (designed, planned, actual). They determined specific energy consumption, including direct consumption of all energy types in the production of a unit of work for primary and auxiliary production and operational needs, including from the consumption volume of mentioned resources and energy supply. Their research showed a 30-40% reduction in energy costs [21]. Based on the results of all the authors presented, we suggest corrective measures in the central area, which is cost reduction. We proposed the corrections measures for cost optimization in the machine park and the synergy effect for the reproduction process (Figure 6).

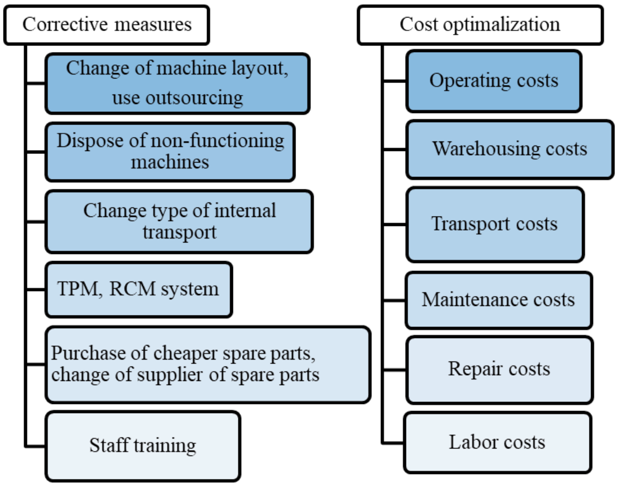

Fig. 6 Corrective measures for cost optimisation

The corrective measures can reduce costs in all CNC machine life cycle phases. Those corrective measures are possibilities for implementing proactive maintenance in the machine park. Kajanová et al. [22] presented information about European business. They commented that the European Green Deal creates a framework for sustainable business and implementing new business models. They presented a new business model. A key aspect of sustainable business is the business environment, based on fairness, transparency, and environmental sustainability principles. Those factors can be obtained by implementing change management in small firms [22]. This proactive model of the machine life cycle accepts the model of sustainable business. Abidi et al. [23] said that the maintenance process represents a supporting process within the IPO chain and is orientated on 3 phases machine life cycle – commissioning, use, reproduction, and disposal. It is essential for creating a safe working environment and maintaining the functionality of machines [23]. Balogh et al. [24] noticed that manufacturing emphasizes the elimination of waste and continuously improving processes [24]. Gonzalo et al. [25] presented that the effective maintenance system includes all technical, administrative, and managerial activities during the object's lifetime, which is intended to maintain it in a state where it can perform the required function to protect it from failure or limitation of its functionality [25]. Husár et al. [26] said that maintenance is a process that means maintaining the workplace, equipment, and machinery in such a condition that they perform their function safely and that their overall condition does not deteriorate. This approach is part of lean management [26]. Malega et al. [27] presented that in the Industry 4.0 landscape, the supply chain becomes a digitally interconnected ecosystem [27]. Markulík et al. [28] presented that there are eight fundamental maintenance indicators: planning effectiveness, inventory of maintenance work, overtime clock, downtime, budget deviations, work performance, maintenance costs, and correct maintenance costs [28]. Tsou et al. [29] commented that embracing digitalization is imperative for staying competitive and ensuring sustainability in the machine park and life cycle [29]. Šaderová et al. [30] presented that the manipulation processes represent an essential maintenance process. They used a simulation model, such as one operational research model, for an effective manipulation process [30]. All this information creates the base for the model. Based on the previous information, we made a Proactive model of the machine's life cycle (Figure 7).

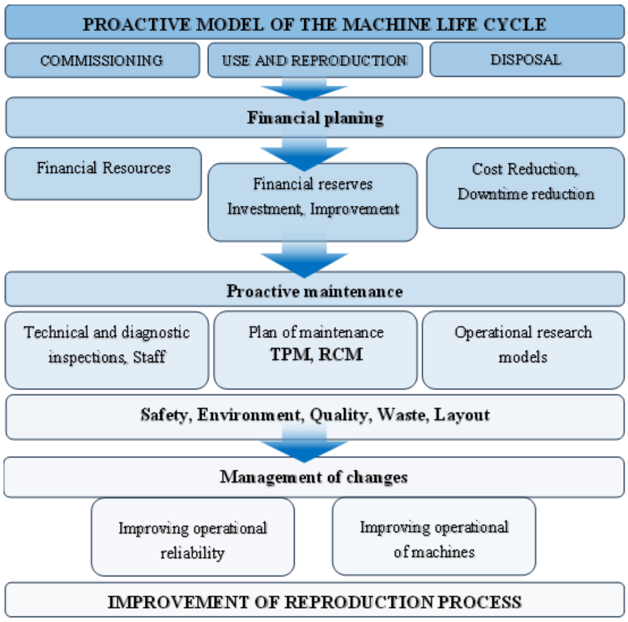

Fig. 7 Proactive model of the machine life cycle

CONCLUSIONS

The machine park is the basic skeleton of the production process in small firms in Slovakia. The scientific discipline of operational research is a significant part of management and is based on improving efficiency, operability, and machine quality. The research was realized in a small enterprise in Slovakia that needed a CNC machine for the production process. The research included Hypothesis H1: Using quantitative models of operational research can manage the machine's life cycle. We used quantitative models of mathematically oriented operational research. The results of the research showed a confirmed hypothesis. Based on the calculations, it was found that the optimal time for the reproduction of the machine is between 5-6 years of its lifetime and its use in praxis in the production process. In the 5th year, the target function acquired the minimum operating costs on level 72736 € for machine operability. The initially planned maintenance and repair costs were €5.850. However, the model determined the sum of costs in the 6th year of use at €8.239, which means an increase in costs associated with a higher failure rate. One of the solutions was the suggestion of the corrections measures for cost optimization in the machine park and synergy effect for the reproduction process and proactive model for the machine park. This model can be recommended for other small firms with functional machine needs.

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