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RESEARCH ON THE EVALUATION OF THE EFFICIENCY OF PRODUCTION PROCESSES THROUGH THE IMPLEMENTATION OF KEY PERFORMANCE INDICATORS

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Abstract:
The paper deals with the implementation of key performance indicators (KPI) for the evaluation of the efficiency of production processes. A key performance indicator is a measurable indicator that expresses how effectively the company achieves key goals in both production and non-production areas. As part of the research, various process key performance indicators characterizing product quality were identified. The indicator of the number of faulty products in relation to the volume of production (*EXTppm*) was chosen for the research. The monthly development of *EXTppm* in the course of 2022 and the long-term development in the years 2012-2022 were evaluated. The research was also devoted to the analysis of the reasons for not achieving the KPI target values, and measures were proposed to eliminate poor quality, respectively reduction of the number of complained products.

Key words: *process performance, key performance indicator, faulty product, production processes efficiency*

INTRODUCTION

The current market demands maximum performance. The pressure on the performance and efficiency of businesses increases with growing competition and a highly competitive environment. Management in companies is aware that achieving and gaining a competitive advantage leads through the efficiency and performance of processes. Currently, only basic financial indicators are no longer sufficient for performance evaluation, which are mostly focused on the past and do not sufficiently show the need to improve specific areas for achieving the company's priority goals. Businesses that want to improve competitiveness must pay attention to other decisive factors for the company's lasting success [1]. An important role is currently played by the evaluation of a wide range of indicators that express the overall performance of processes. We call them key performance indicators.

Key Performance Indicators (KPI) are among the most common process efficiency indicators nowadays. This term refers to indicators, i.e. performance indicators and metrics assigned to a process, service, organizational unit, or the entire organization. KPI indicators express the required performance such as quality, efficiency, or economy of the evaluated unit. They are used at all levels of organizational management, especially in strategic management and management by goals and service management [2, 3].

The implementation of KPI in the environment of a manufacturing company is a demanding and long-term process [4, 5]. One of the most important components for the successful management of this process is the support of top management, senior staff and, last but not least, the employees themselves working in the positions to which the introduced KPIs relate [6]. Without conviction about the importance and adequate cooperation of the mentioned components, even the implementation itself cannot be successful. The basis of the success of KPI implementation in a manufacturing company is to acquaint all interested workers with the benefits that a given solution can bring them. Furthermore, it is important to gain their enthusiasm and trust for the KPI implementation project.

LITERATURE REVIEW

Key performance indicators (KPIs) are metrics that focus on those aspects of an organization's performance that are most important to the organization's current and future success. Measuring the performance of processes represents activities that are supposed to provide objective and accurate information about the course of individual processes so that these processes can be continuously managed by their owners so that all the requirements placed on these processes will be met.

In the standard ISO 9004:2018 in article 8.3.2, key performance indicators are defined as factors that the organization controls and which are critical. These must be marked as key performance indicators. They must be subject to performance measurement for its continuous success [7]. Key performance indicators (KPIs) serve as a managerial tool to track, manage (noting deviations for corrective action), and ensure the attainment of desired performance levels within activities or processes. Utilizing the KPIs approach can enhance employee performance evaluations by comparing actual outcomes to predefined targets. Successful implementation hinges on employing a robust maintenance strategy aligned with established directives [8]. KPIs encompass a set of measurable indicators that gauge the alignment of an organization's strategic goals with its accomplishments. The components of KPIs include strategic objectives, pertinent indicators linked to these goals, benchmarks, and the designated timeframe [9]. KPIs is considered as a new initiative in performance measurement. The success of KPIs in various institutions to assess the achievement of activity implementation based on strategic plans so that the progress of the organization can be known and to improve the quality of decision making and accountability.

KPIs must correspond to the nature and size of the organization and its products, processes, and activities. They must be in line with the goals of the organization, which on the other hand must correspond to its strategy and policy. For the selection of KPIs, the following must be taken into consideration:

- Needs and expectations of customers and other interested parties.
- The importance of individual products for the organization both now and in the future.
- Performance and efficiency of processes.
- Economical and effective use of resources.
- Profitability and financial performance.
- Requirements of regulations and laws, if necessary [10].

Numerous published research papers have tackled the definition and identification of the advantages associated with the incorporation of KPIs into business operations [11, 12, 13]. KPIs are, undoubtedly, the essential measurement and control tools within all the processes of an organization. These indicators allow identifying if the activities are being carried out efficiently, and help optimizing all the resources involved [14]. KPIs must reflect the corporate strategy and competitive factors of the organization, and they must focus on the method to achieve results [15, 16, 17]. KPIs have also to be meaningful, coherent, objective driven, and a standard for objectively comparing different organizations [2]. It can be asserted that all authors are in agreement regarding the paramount contribution of KPIs, which lies in enhancing the efficiency of business processes and elevating product quality by introducing measurable production indicators [18, 14, 19].

Upon reviewing the numerous sources, it is evident that the adoption of KPIs yields several advantages for institutions and agencies, including the following:

1. Facilitating more streamlined reward and penalty systems for managers,
2. Offering transparent and targeted employee growth pathways,
3. Enhancing managerial decision-making processes,
4. Rendering job appraisals more objective and purposeful,
5. Amplifying organizational effectiveness,
6. Bolstering productivity,
7. Elevating service quality,
8. Establishing safety metrics [5, 20, 21, 22].

MATERIALS AND METHODS

After defining the concept of key performance indicators, the relationship between quality, productivity and performance, the starting points for measuring process performance and a set of requirements for measuring the processes themselves, we can proceed to the choice of indicators for measuring process performance. When determining the performance measurement characteristics of the process, it is necessary to accept the following conditions:

- Precise definition of the process to be measured. That is the role of the organization's leadership or management of the relevant organizational unit.
- Formation of a group of workers who will be responsible for the choice of indicators, while they must be experienced workers and the owner of the process.
- Brainstorming. The moderator is the owner of the process and the task is to collect as many relevant stimuli as possible.
- The very selection of the most suitable indicator is based on brainstorming.
- Designing mathematical relationships for calculating the performance of process indicators.

It is important to establish the necessary information inputs for the calculation of performance indicators by the process owner. Performance indicators have a certain universality. However, their character is always related to the uniqueness of the monitored process itself. For our research, we based our evaluation on the proportion of non-conformity in the process *Pn*:

$$Pn = \frac{On}{Oc} \cdot 100\ [\%] \quad (1)$$

where:

On – volume of non-conformity detected during verification in the process;

Oc – the total volume of identical outputs from the process in a certain time [23].

Measuring process performance by deviations is the simplest form of evaluation. A subtle deviation in this case means a deviation from normal or the same process requirements. It is an indirect method of evaluating a performance indicator. The types of processes evaluated in this way are input delays, material and informational, incapacity of the worker, errors or deficiencies in the documentation for the activity being performed, defects in tools or aids, untested software, uncontrolled changes made outside the documentation, power outages and the like.

The research was carried out in an engineering company that deals with chip machining of metal and non-metal parts [24]. The products of analysed company (Fig. 1) are used in window system mechanisms, the furniture industry, hydraulic aggregates, but above all in the manufactures of renowned car companies and manufacturers of heavy trucks.

Fig. 1 Sample of manufactured components

Production consists of a wide range of parts produced mainly by chip machining technology, from simple turned parts to complex machined parts finished by grinding, rolling or milling. The main focus is CNC machining of metal and non-metal parts. The essence of production technology is represented by machining centers, CNC lathes working mainly with bar material and compact horizontal centers. The product is turned and milled parts, which can then be finished by grinding, thread rolling or drilling. The company monitors primary order indicators of a financial nature, but is aware of the importance and necessity of starting to monitor indicators that express the overall performance of processes.

The KPI implementation process in the analyzed company was divided into steps, the fulfillment of which is important for the success of the KPI implementation itself. The importance of the order of fulfillment of individual steps is fundamental both in planning and in the actual implementation of introducing KPIs into company processes.

For planning the individual steps of KPI implementation into production processes, an algorithm was compiled that defines the individual steps of the KPI implementation procedure, as well as the evaluation of process performance and the subsequent adoption of measures in the event of non-achievement of goals:

- Step 1. Creating a process map.
- Step 2. Determination, identification of processes and process owners that will be measured.
- Step 3. Defining key process performance indicators.
- Step 4. Data sources, input measurement of values for selected KPIs.
- Step 5. Analyzing and reporting current process performance.
- Step 6. Evaluation of the fulfillment of process performance goals.
- Step 7. Determination of measures to improve process performance.
- Step 8. Verification of compliance with measures and repetition of ongoing data collection and subsequent analysis of collected data [25, 26].

KPIs for the evaluated production were subsequently designed based on Step 3. The identified indicators characterizing the quality of the product are number of complaints, fulfillment of the plan, number of non-conformities, total productivity, production time per unit of production (Fig. 2).

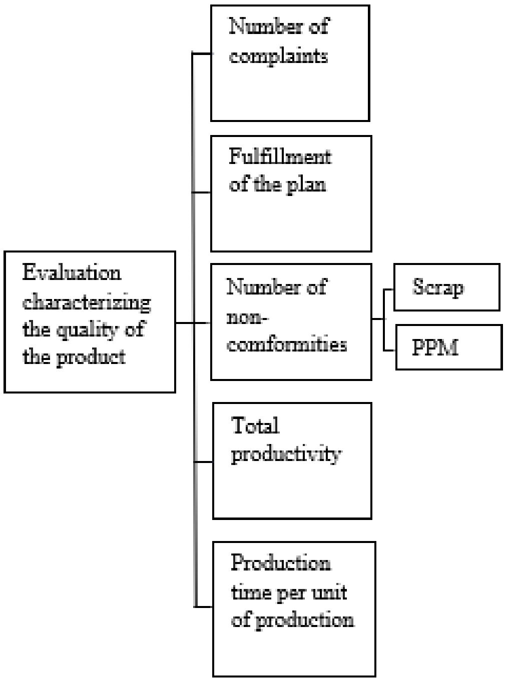

Fig. 2 KPIs characterizing product quality

KPI monthly evaluation of the number of faulty products was used to analyze and report the current process performance. The result is a value expressed in ppm as external ppm for a period of one month. The inputs are the number of delivered parts for a period of one month and the number of faulty parts for the same period. This result is mainly an expression of the quality of the supply of parts for a period of one month. External ppm for a period of one-month *EXTppm_{monthly}* is expressed:

$$EXTppm_{monthly} = \frac{On}{Oc} \cdot 1000000 \qquad (2)$$

where:

On – the cumulative volume of complained non-conformity over a period of one month;

Oc – cumulative volume of products delivered over a period of one month.

Annual assessment of the faulty products number being reported as another performance evaluation indicator for the processes. The result is a value expressed in ppm as external ppm for a period of one year (3). The inputs are the sums of calculated external ppm for individual months and the number of months of the monitored period. The result is the total external ppm achieved during the monitored period of one, at the same time, this data is equal to the last evaluated month.

External ppm for a period of one year $EXTppm_{annual}$ is expressed as:

$$EXTppm_{annual} = \frac{\sum EXTppm_{monthly}}{12}, \qquad (3)$$

where:

$EXTppm_{annual}$ – external ppm for a period of one month according to (2).

RESULTS AND DISCUSSION

An 8-step algorithm, presented in the previous chapter, was used in the identification and design of the KPI implementation procedure in the analyzed company. After putting the procedure into practice, individual KPIs were subsequently evaluated based on the data obtained. The identified KPIs were defined as precisely as possible for the comprehensibility of all interested parties and the possibility of clear and correct monitoring.

Data processing must be in an adequate form for easy understanding of process performance evaluation. It must be purposefully and time-ordered so that trends of future development can be drawn up from the collected data at the same time. Trends give us the collected data in the context of time. They inform us about the development over a certain period of time and the possible direction in the future. They show us whether our measures for improving processes were correct and whether they led to the desired effects.

The research was focused on the evaluation of the performance of production processes characterizing the quality of the product, namely the monthly evaluation of the number of faulty products $EXTppm_{monthly}$. The results of the development of the monitored KPI were evaluated retrospectively for the previous year, as an example of the development trend during the year.

The evaluation of complaints was based on the number of complained products. We evaluated the period of the last year for each month separately. Subsequently, we assessed the number of faulty products by comparing individual years over the last ten years. The monthly assessment was carried out using the ppm method, from which the annual assessment was subsequently expressed. The collected data on the number of complained products were evaluated monthly for individual months and in total for the whole year, once a year. For the evaluation of the long-term performance of production processes according to the number of non-conforming products, the relevant period was from January 1, 2012 to December 31, 2022. In the period from 1.1. In 2012, the collection of data on non-conforming products in production began in the company-wide information program Dialog. Collected data on non-conforming products is at a frequency of once per shift and covers the entire production period of the product. The daily assessment was in the form of a percentage value of the proportion of non-conforming parts to conforming parts.

The result of data collection for the analysed KPIs are calculated cumulative values of external ppm for individual months expressed using (2). In the graph presented in Fig. 3 are shown the total quantities of delivered parts and the specific number of faulty parts for a period of one month during the year 2022.

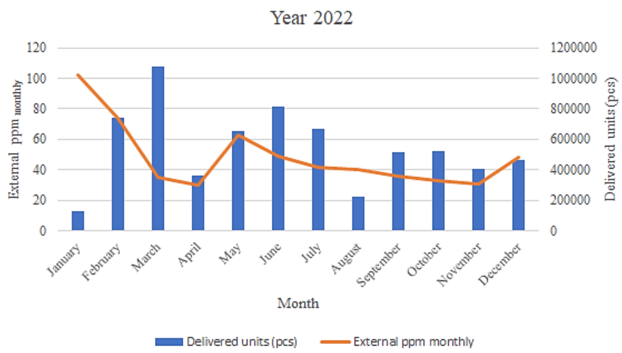

Fig. 3 Comparison of the number of delivered units and the development of external ppm for faulty units

Subsequently, a comparison was made of the development of the annual external ppm (3) for a period of 10 years based on historical data obtained from the Dialog corporate information system. The graph (Fig. 4) is compiled from the calculated values of external ppm for individual years and the total number of delivered units for individual years.

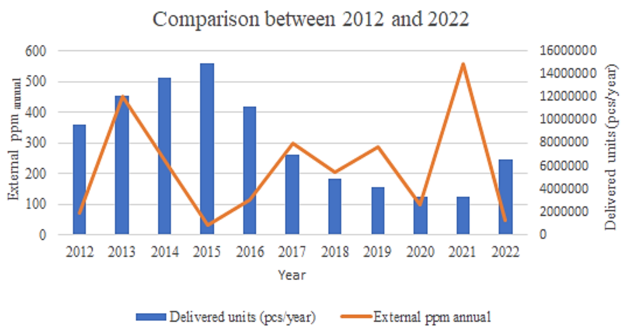

Fig. 4 Comparison of the quantity of supplied units and the development of external annual ppm for faulty units over a period of 11 years

The purpose of the graph (Fig. 4) is to capture the mutual correlation between the number of delivered units and the quantity of units reported as faulty. The above display provides the company with the basis for evaluating the performance of processes in terms of long-term development and trends. It is also the basis for setting KPI target values as a starting point for improving business processes.

The identified KPIs were defined as precisely as possible for the comprehensibility for of all interested parties and the possibility of clear and correct monitoring. KPIs are quantifiable and assessable even during the ongoing process and have associated units.

The company's management together with the process owners determine the target values of individual KPIs based on the determined quality goals, data collected so far and operational goals. These values and their fulfilment represent the achievement of the desired state of the process. The company sets quality goals every year as required by the STN EN ISO 9001:2016 standard.

The external ppm value of the analysed company was determined from the company's quality goals for the year 2023. The quality goal for the year 2023 is to keep the external ppm below 300 ppm. The external ppm value is linked to the monthly assessment of the number of complained products, the annual assessment of the number of complained products and thus also to the comparison of the annual external ppm over a period of 10 years. The goal is to keep both monthly ($EXTppm_{monthly}$) and annual ($EXTppm_{annual}$) ppm below the target value of 300 ppm.

When evaluating the development trend of the monitored KPI: $EXTppm_{annual}$ for the period of 10 years shown in Fig. 4, we looked for the causes of high KPI values achieved in certain years. After taking into consideration all circumstances, economic and socio-societal influences, we can conclude that the maximization of the trend curve in certain years was caused by:

- Year 2013 – the hiring of new employees due to the expansion of production after the end of the crisis caused the quality of production to be unstable.
- Years 2017, 2019 – high turnover of employees, new start-up series in production still had shortcomings and were therefore not under sufficient control.
- Year 2021 – qualified employees left the company during the Corona crisis and newly hired employees did not have the necessary experience, which caused a renewed increase in poor quality when the market recovered and the production volume increased.

The company was engaged with the adverse development in the number of customer complaints and several measures were taken to stop the adverse development. The most effective measures were:

- Pay close attention to the quality of processes and the reliability of machines.
- Inclusion of a random 10% inspection of individual products made by each worker after the end of the shift.
- Mentoring of new workers.
- Creating a training plan with checkpoints of acquired skills and knowledge.
- Stabilization of the team of workers.

CONCLUSION

For effective functioning and consolidation of the market position, it is important to monitor individual activities in the company. For this purpose, it is advisable to introduce key process performance indicators that will enable a more accurate assessment of the company's current state and viability. KPIs are different for every company. There are several key indicators intended for the manufacturing and non-manufacturing spheres, but even so, key performance indicators must be determined by each company individually. Because of this, setting the right KPIs is a challenge for businesses. KPI monitoring creates a process by which an organization identifies and sets operational goals to ensure and improve process performance.

The aim of the research presented in the article was to propose a procedure for the implementation of key indicators of the performance of production processes and to determine the values of the measured indicators. The evaluated KPI was the number of complained products expressed through the *EXTppm* indicator, while the development of the KPI during the 12 months of the calendar year 2022 was analyzed, as well as the long-term development of the indicator during the years 2012-2022. As part of the implementation of the mentioned KPI, a procedure for collecting relevant data from the Dialog information system was created in the company, the methodology for calculating *EXTppm* was determined and a suitable method of graphical display of the results was designed. When analyzing the results, the causes of high *EXTppm* values in certain years were identified and measures were proposed to stabilize the achievement of KPI target values.

The main benefit of KPI implementation for the company is the possibility to analyze individual processes through their overall performance, and not only from a purely financial point of view. By introducing KPI, each company will get an analytical tool quantifying the performance of processes in relation to a set goal related to the achievement of the desired result, which can stabilize the quality and reliability of its processes and thereby meet the requirements of the standard.

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