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Key performance indicators as a tool for evaluating efficiency of production processes

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Abstract: This paper deals with the topic of Key Performance Indicators as a tool for evaluating the efficiency of production processes. In the current competitive market environment, manufacturing enterprises face increasing demands for maximizing efficiency and performance. Traditional financial indicators often fail to capture the complexity of process improvement, necessitating a shift towards more comprehensive evaluation methods. Key Performance Indicators (KPIs) have become essential tools for assessing production efficiency, providing a framework for monitoring, measuring, and optimizing various production activities. This paper examines the implementation and benefits of KPIs in an engineering company specializing in CNC machining of metallic and non-metallic components. The research outlines a step-by-step algorithm for KPI integration, including process mapping, identification of process owners, data collection, and performance evaluation. The study specifically focuses on the KPI "number of non-conformities" to assess production stability over a 16-month period, using internal parts per million (ppm) metrics. The results demonstrate the role of KPIs in improving transparency, enhancing decision-making quality, and supporting continuous improvement initiatives. Furthermore, the paper discusses the importance of adapting to market trends, such as technological innovations and legislative changes, to maintain a competitive advantage. The findings indicate that the strategic use of KPIs allows companies not only to track operational performance but also to proactively respond to industry changes, thus fostering sustainable growth.

1 Introduction

The current competitive market environment imposes high demands on the maximum performance of manufacturing enterprises. With increasing competition and a high level of competitiveness, the pressure on the performance and efficiency of companies is growing. Enterprise management recognizes that achieving and gaining a competitive advantage leads through efficiency and process performance. Therefore, it is important to monitor individual activities within the company to operate efficiently and strengthen market position.

Current basic financial indicators, which mostly focus on the past and inadequately reflect the need for improvement in specific areas to achieve the company's priority goals, are no longer sufficient for performance evaluation. Companies aiming to enhance their competitiveness must also pay attention to other decisive factors for the sustained success of the enterprise. These may include implementing sustainability practices, which not only reduce costs but also improve the company's reputation. Assessing a wide range of relevant indicators that express the overall performance of processes plays a significant role in today's context. These indicators are referred to as key performance indicators.

For a better understanding of the current market situation, it is necessary to consider other aspects that influence the performance and competitiveness of the enterprise. These factors may include innovation, investment in human resources, development of new products and services, as well as improvement of management processes and communication within the company. The role of employee engagement has also emerged as a critical factor, directly affecting productivity and process outcomes. Effectively utilizing these aspects can have a crucial impact on the long-term success and sustainable growth of the enterprise.

Additionally, it is important to pay attention to rapid changes and trends in the industry that may affect the company's competitive position. This includes technological innovations, legislative changes, changes in consumer preferences, and other factors that can have a significant impact on the company's performance. Companies that actively monitor these changes and incorporate predictive analytics into their strategy are better equipped to stay ahead. Therefore, it is necessary for enterprise management to be able to react flexibly to these changes and adjust their strategy according to the current market situation. In conclusion, it is crucial for companies to maintain flexibility and adaptability in order to successfully compete in a dynamic and constantly changing market environment.

2 Literature review

Key Performance Indicators (KPIs) are among the most common indicators of process efficiency in today's context. This term refers to indicators, i.e., performance metrics and measures assigned to a process, service, organizational unit, or the entire organization. KPIs express the desired performance by assessing the quality, efficiency, or economy of the evaluated entity. They are used at all levels of organizational management, primarily in strategic management, goal-oriented management, and service management [1].

In the standard STN EN ISO 9004:2010 [2], in chapter 8.3.2, key performance indicators are defined as factors that an organization controls and are critical to its sustained success. These must undergo performance measurement and be identified as key performance indicators (STN EN ISO 9004:2010). KPIs are undoubtedly essential tools for measuring and controlling all processes within an organization. These indicators allow for the identification of whether activities are being carried out effectively and help optimize all involved resources. KPIs must reflect the organization's corporate strategy and competitive factors and should focus on how results are achieved [3,4]. KPIs must also be meaningful, coherent, goal-driven, and standardized for objective comparison across different organizations [5]. Many published research papers have dealt with defining and identifying the benefits associated with implementing KPIs into business processes [6,7]. We can state that all authors agree that the most significant contribution of KPIs lies in increasing the efficiency of business processes and improving product quality by introducing measurable production indicators [8,9].

After reviewing numerous literary sources, it is evident that the implementation of key performance indicators brings many advantages to businesses that decide to adopt them. The following benefits are prioritized: providing transparent goals for employees, enhancing productivity, improving the quality of managerial decision-making processes, making performance evaluations more objective and purposeful, strengthening organizational efficiency, enhancing the quality of services provided, and establishing clear safety metrics [10-13].

3 Methodology for implementing key performance indicators in a manufacturing company

The research was conducted in an engineering company specializing in the machining of both metallic and non-metallic components using cutting processes [14]. The products of the analysed company (Figure 1) are utilized in window system mechanisms, the furniture industry, hydraulic units, and primarily in products manufactured by renowned automobile producers, as well as manufacturers of heavy-duty vehicles.

The production involves a wide range of components manufactured mainly through cutting processes, ranging from simple turned parts to intricately machined pieces finished through grinding, threading, rolling, or milling. The primary manufacturing process is CNC machining of both metallic and non-metallic parts. The essence of the production technology is represented by machining centres, CNC lathes predominantly working with bar material, and compact horizontal centres. The products consist of turned and milled components, which can subsequently undergo finishing processes such as grinding, thread rolling, or drilling. The company primarily monitors order-based financial indicators, but it considers it important and necessary to begin tracking indicators that express the overall performance of processes.

The implementation process of KPIs in the analysed company was divided into steps, the fulfilment of which is crucial for the success of the KPI implementation itself. The sequence of carrying out these steps is vital both in the planning phase and during the actual implementation of KPIs into the company's processes.

Figure 1 Example of manufactured components

For the planning of individual steps of KPI implementation into production processes, an algorithm was developed. This algorithm defines the specific steps of introducing KPIs, as well as the assessment of process performance and subsequent actions in case of not achieving the goals:

Step 1. Creation of processes maps.

Step 2. Identification and determination of processes and process owners to be measured.

Step 3. Definition of key performance indicators for the process.

Step 4. Data sources, input measurements for selected KPIs.

Step 5. Analysis and reporting of current process performance.

Step 6. Evaluation of the achievement of process performance goals.

Step 7. Identification of actions for improving process performance.

Step 8. Verification of action implementation, and ongoing data collection and subsequent data analysis.

Based on Step 3, KPIs relevant to the evaluated production were subsequently designed. The identified indicators characterizing product quality include: the number of complaints, plan fulfilment, the number of non-conformities, overall productivity, and production time per unit.

4 Results and discussion

For the purposes of our research, we selected the KPI "number of non-conformities" [14]. Specifically, the performance of orders for part A was assessed based on the number of non-conforming pieces over the total duration of the orders during the 16 months of 2022 and 2023. The result is an expression of internal ppm (parts per million) for part A for each individual order (Table 1). The evaluation is always conducted for the production period of a specific order after its completion. The inputs are the number of produced products per order and the number of non-conforming products generated during that specific order. The indicator INTppm (1) represents the overall production stability for the duration of a particular order during the evaluated period:

$$INT_{ppm} = \frac{Q_n}{Q_t} \cdot 1000000 \qquad (1)$$

Where:
Qn – quantity of non-conforming products in the order,
Qt – total quantity of products manufactured in the given order.

In the graph (Figure 2), the values from the table (Table 1) are visually represented. The graph illustrates a comparative analysis between the quantities of produced pieces per order and the internal ppm per order.

Table 1 Evaluation of order performance for part a using INTppm for the evaluated period

Order Number	Order Completion Date	Total Quantity of Produced Part A in the Order (*Qt*)	Quantity of Non-Conforming Part A in the Order (*Qn*)	Internal ppm (*INTppm*)
1	3.1.2022	1536	5	3255
2	27.1. 2022	1536	0	0
3	24.2. 2022	1536	1	651
4	9.3. 2022	2304	2	868
5	21.4.2022	2304	29	12587
6	28.6.2022	2000	3	1500
7	21.7. 2022	2304	22	9549
8	1.8. 2022	2022	14	6076
9	9.9. 2022	2152	12	5576
10	10.10. 2022	2304	5	2170
11	7.11. 2022	890	8	8989
12	19.12. 2022	1536	16	10417
13	13.1. 2023	1152	5	4340
14	15.2. 2023	1920	5	2604
15	22.3. 2023	2304	0	0
16	15.4. 2023	2000	5	2500

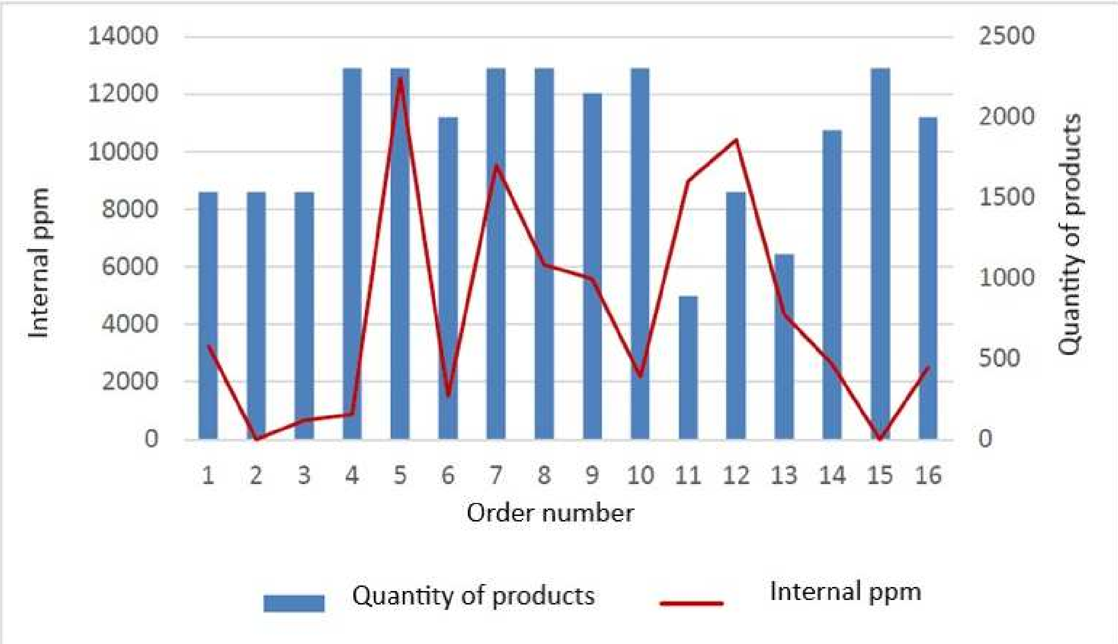

Figure 2 Graphical evaluation of order performance for part a using internal ppm INTppm

When evaluating the results displayed in the graph in Figure 2, it can be observed that the INTppm values exhibit a highly fluctuating tendency, reflecting the instability of the assessed process. The target value for the evaluated KPI is the value of the overall internal ppm, which was set as a quality target for the company in 2022 and 2023, with a maximum value of 2000 ppm. Therefore, the target INTppm value is to achieve a maximum of 2000 ppm for each evaluated order for part A. The achieved average value for individual part A orders during the monitored period, encompassing 16 initiated and completed orders, was 4443 ppm. This indicates that the company's goals in terms of quality and process performance were not met for the specific part A orders. In the analysed company, each non-conforming part is recorded in the company-wide information system called Dialog. Besides the count of non-conforming products, the system allows for entering a description of the non-conformity and its root cause. Following an analysis of the records in collaboration with production operators, production managers, technologists, and quality department personnel, the following descriptions and causes of non-conforming products were identified:

1. Short piece after turning operation, with the cause stated as "clamping error" in the turning operation.

2. Damaged piece, with the cause indicated as "worn cutting insert, need for replacement of the cutting insert."

To eliminate the occurrence of non-conforming pieces, it was necessary to address the identified causes of non-conformities. Based on an analysis of the causes of non-conformities in the analysed process and feedback from stakeholders regarding the issue, the following actions were agreed upon:

1. Elimination of the cause of improper clamping during turning - The technologist will consider the possibility of modifying the clamping process, adjusting the stop, and re-turning the soft jaws of the chuck. The stop against which the part rests during clamping needs to be adjusted so that the part is supported at multiple points, thereby eliminating the possibility of skewed clamping of the part in the chuck.
2. Removal of the cause of worn cutting inserts and timely replacement of cutting inserts during the turning operation involves appropriate diagnosis of the problem and machine maintenance. Preventing the wear of cutting inserts and the resulting non-conforming parts involves specifying an appropriate replacement interval for the cutting insert. The frequency of cutting insert replacement can be determined based on the guidelines provided by the cutting insert suppliers and verified during subsequent production orders. The process of changing the cutting insert is also critical, and it can prevent the occurrence of the first non-conforming piece by focusing on critical dimensions. In this case, the critical dimension is the overall length of the product, which can be adjusted with a suitable excess and subsequent correction.

5 Conclusion

The integration of key performance indicators (KPIs) within the manufacturing company setting is a complex and lengthy endeavor. To effectively manage this process, the support of upper management, supervisors, and employees in positions related to the implemented KPIs is essential. By monitoring KPIs, organizations establish a systematic approach to identify and establish operational objectives aimed at improving process efficiency. The objective of the study outlined in the paper was to propose a methodology for integrating key performance indicators into production processes and determining the metrics' values.

The identified KPIs were precisely defined to ensure clarity and accuracy for all stakeholders, facilitating transparent monitoring. These indicators are measurable and evaluable even during ongoing processes, with corresponding units assigned for assessment. The primary benefit of KPI implementation for a company lies in its capacity to analyze individual processes holistically, beyond mere financial metrics. Through the introduction of KPIs, companies acquire an analytical tool to quantify process performance relative to predefined goals, thereby enhancing stability and reliability while meeting regulatory standards [15].

The research focused on evaluating the performance of production processes with regard to product quality. The target performance value for part A production processes, based on non-conforming product counts, was defined as the INTppm value. The target INTppm value, aligned with the company's quality objectives, aimed to achieve a maximum value of 2000 ppm for each assessed part A order. However, the average value attained for individual part A orders over the observed period, encompassing 16 initiated and completed orders, was 4443 ppm. Consequently, the company's quality and process performance targets for specific part A orders were not met, indicating a highly unstable process. In response, actions were proposed to address the identified quality issue by modifying the lathe chuck design and implementing timely diagnosis and maintenance of problematic cutting inserts, with the goal of rectifying the quality concerns [16,17].

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