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Cost optimization of heavy quarry machinery by benchmarking

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Abstract
The article focuses on the importance of benchmarking in maintenance processes. Maintenance benchmarking is a process used by organizations to evaluate and improve their maintenance practices and performance by comparing them to industry standards or best practices. The goal of maintenance benchmarking is to identify areas for improvement, optimize resource allocation, and enhance overall operational efficiency. The changing environment of small and medium-sized enterprises in recent years has produced new pressures and concerns. In this present environment and in the future, successful companies will be those that can continually improve and adapt their services to meet and exceed the demands of stakeholders. The goal of the improvement might concern the actual quality of the state of the environment in one case, whereas in another case, the focus could be on environmental costs or the satisfaction of the citizens with environmental services. The benchmarking type used and the benchmarking objectives will influence the criteria for choosing benchmarking partners. Benchmarking is currently one of the most effective industrial performance improvement processes. In this regard, benchmarking, formal and structured observation, and exchanging ideas between organizations may prove to be valuable tools.

Keywords
Maintenance, benchmarking, quarry, heavy mechanism, international company.

Introduction

Nowadays, many companies realize that if they want to succeed in the market, they have to undergo many changes. However, these changes would represent a long period, and businesses must base themselves on the options available to them. They often encounter problems associated with outdated technology, low company culture, the educational level of workers, and a decline in product quality and competition. Traditional approaches, models, methods, and ways of working for companies reach their extreme possibilities. They are not able to react flexibly to new, dynamically changing conditions (Derkawi, 2023). Therefore, other solutions are gradually emerging for companies that are pursuing their prosperity in the new conditions of globalization of society. Solutions that accept changes in the market but at the same time trigger the introduction of new approaches to work and the associated reorganization of companies (Mourão and Popescu, 2023; Ključnikov et al. 2022). Benchmarking is the process of improving an organization's behaviour by identifying, understanding, adapting, and implementing best practices and processes that can be found inside or outside the organization (Belas et al. 2020; Gavurova et al. 2022). Although American scientists methodically specified the term "benchmarking "in 1972, its interpretation constantly evolves. The purpose of benchmarking is to determine, based on research, the need for change and the probability of success as a result of these changes. Benchmarking is done as part of competitive analysis and is not new to most businesses, although it has a more detailed and effective function than the competitive analysis method or approach (Kingdom, Jagannathan, 2001; Skare et al. 2023a). In general, benchmarking involves defining a set of tests or tasks that the system or product must perform and then measuring the time or resources required to complete those tasks. The benchmarking results can be used to identify areas where performance can be improved and to compare the performance of different systems or products (Tkacova and Gavurova, 2023; Muangmee et al. 2022).

Benchmarking does not itself explain why an organization might not be performing properly. The whole exercise is rather pointless if efforts are not made to understand the causes of an organization's shortcomings (Pavolová, 2021; Olczyk et al. 2022). Priority should be given to benchmarking performance areas that result in an organization's success. In profit-seeking organizations, competitive advantage can be achieved either by cost leadership or by differentiation (Bednárová, 2018). Another approach that can indicate where benchmarking would be particularly useful is to examine an organization's value chain (Gavurova et al. 2020; Skare et al. 2023b). The rationale behind the value chain is that because an organization spends time, money, and effort carrying out the various activities, the organization manages to make a profit. In other words, customers are willing to spend more on what the organization produces than all the activities, leading to production costs. It means that the organization must be doing more than is explicitly depicted on the value chain: this is the value-added. For example, because of its size, the organization might have access to economies of scale that are not available to customers. On the other hand, the organization might be using the knowledge that customers do not possess.

According to Watson (1994), there are three significant advantages to conducting comparative studies.

- First, benchmarking provides an independent assessment of how well a process is working, evaluating the performance of similar processes in different organizations or units within a single organization. By measuring the performance of other organizations or other organizational units, an objective basis for realistic quantitative performance targets can be established.
- Second, benchmarking provides an incentive to make groundbreaking change initiatives a reality by increasing the creativity and innovation of teams working to improve processes.
- Third, benchmarking expands the experience base of the organization or units. Looking at the experience of other organizations externally or other units internally, benchmarking provides examples of behaviours, systems, and methods that enable better performance, as well as insights into things that do not work as well.

The concept of benchmarking is not very new since, in the history of business development, there have been many cases where one company took over the experiences of others to achieve success. Back in the early twentieth century, H. Ford enacted his famous conveyor to assemble cars after a trip to Chicago, where he watched the slaughterhouse butchering, hanging on hooks that were moved along the monorail from one workplace to another (Foreman-Peck, 2006).

Benchmarking is one of the most well-known methods for business improvement. There are various definitions of this term in the literature; for example, benchmarking is:

- An improvement process that is used to find and implement the best practices in one's own activity (Damelio, 1995), the best practice here refers to a method or technology used for production (marketing, business, purchasing, etc.) process;
- A method of establishing the current projects and plans for productivity based on the best practices in the industry aimed at improving performance (Camp, 2006);
- Process of continuous evaluation and comparison of the organization with the worldwide leading companies to obtain information that will help the organization to take action to improve its performance (APQC, 2006);

In general, benchmarking involves defining a set of tests or tasks that the system or product must perform and then measuring the time or resources required to complete those tasks. The benchmarking results can be used to identify areas where performance can be improved and to compare the performance of different systems or products. Benchmarking can be used in a variety of fields, including business, manufacturing, healthcare, and education. It can help organizations identify areas for improvement, set performance goals, and measure progress over time.

Materials and Methods

The benchmarking procedure is based on a systematic comparison of organizational processes and performances. There is no benchmarking methodology that could be simply adopted. However, there are common features of benchmarking that allow speaking about the benchmarking method and necessary steps to be done within the benchmarking Figure 1 (Blanchard, 2014). The assessments carried by these tools cover company practices (leadership, policy and strategy, attention given to the customers and to the market, human resources, information management, etc.) as well as the results of the performance obtained by the company (performance of the processes, the satisfaction of the customers, the performance of the partnerships and the suppliers, financial results, etc.). Benchmarking is a strategic tool that helps organizations assess their performance, identify areas for improvement, and adapt to changing market conditions (Samal, 2021). It can lead to increased efficiency, cost savings, and a stronger competitive position in the market.

The method generally used to describe a process is based on an input/output approach and on a formalization of the sequence of activities that make up the process (Cattan et al., 2006). Generally, these inputs and outputs refer to elements that are part of the physical flow or information flow of the process. The representation obtained makes it possible to have a description of the activities as well as a description of how these activities must interact for the process to deliver the expected result.

To describe the processes, we chose a systemic approach (LeMoigne, 1993), including a description of the activities in the process but also a description of its structure and history. To solve the problem, we use standard methodology with 12 gaps for benchmarking as a:

1. Define Objectives and Scope:
   - Clearly define what you want to benchmark. It could be a specific process, department, or entire organization.
   - Set clear and specific objectives. What do you want to achieve through benchmarking?
   - Identify Benchmarking Partners:
   - Determine who you will benchmark against. It can be competitors, companies from other industries, or even internal departments or divisions.

2. Identify Key Performance Metrics:
   - Select relevant performance metrics that align with your objectives.
   - Ensure that these metrics are measurable, specific, and meaningful to your organization.

3. Select Benchmarking Partners:
   - Identify organizations or entities that are appropriate for benchmarking.
   - These could be competitors, industry leaders, or organizations with best practices in the areas you are interested in.

4. Data Collection:
   - Gather data on the processes or areas you want to benchmark. This data might include metrics, performance data, and information on the processes involved.

5. Choose Benchmarking Methods:

There are several types of benchmarking, but for our research, we chose internal benchmarking, which compares a process or department within your organization to another within the same organization. It is necessary to choose the method that best suits our objectives (Petterson, 1996).

6. Collect Data from Benchmarking Partners:

Gather data from your selected benchmarking partners. This might involve surveys, site visits, or accessing publicly available information.

Data Analysis:

- Analyze the collected data to identify gaps, areas of improvement, and best practices.
- Compare your performance with that of your benchmarking partners.

Set Targets and Goals:

- Based on your analysis, set specific targets and goals for improvement.

Develop an Action Plan:

- Create an action plan that outlines the steps needed to reach your improvement goals.
- Assign responsibilities and timelines.

Implement Changes:

- Execute the action plan.
- Ensure that the changes are well-documented, communicated, and monitored.

Evaluate and Continuously Improve:

- Continuously assess the impact of the changes made as a result of benchmarking.
- Make adjustments to the action plan and strategies as necessary.
- Repeat the benchmarking process periodically to maintain competitiveness and continuous improvement (Mueller,2023)

7. Identify Best Practices:
   - Identify the specific best practices that lead to superior performance in the areas you're benchmarking.
   - Consider both process-related and strategic practices.

8. Gap Analysis:
   - Identify the gaps between your current performance and the benchmark.
   - Understand the reasons for these gaps.

9. Develop an Action Plan:
   - Create a detailed action plan for implementing the best practices you've identified.
   - Set clear goals and timelines for improvement.

10. Share Best Practices:
    - If you discover best practices during the benchmarking process, consider sharing your own best practices with others.
    - It's a two-way learning process.
    - Benchmarking is an ongoing process.
    - Continue to seek out new benchmarks and make continuous improvements to maintain or enhance your competitive position**.**

11. Document the Process:
    - Keep detailed records of the entire benchmarking process, including the data collected, analyses, action plans, and outcomes.

12. Legal and Ethical Considerations:
    - Be aware of legal and ethical considerations when sharing and using data from benchmarking partners.

Benchmarking is a valuable tool for identifying areas where performance can be improved, but it requires a structured approach to be effective.

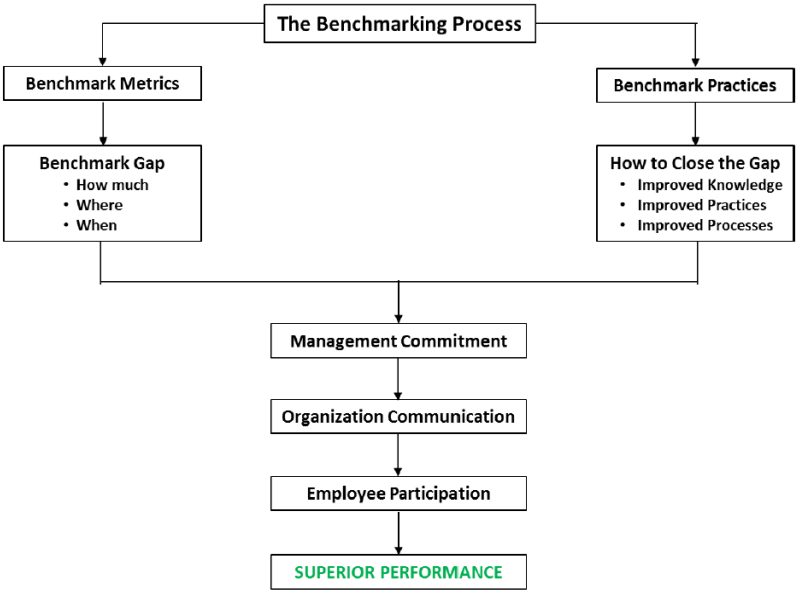

Fig. 1. Basic Benchmarking Process based on (Blanchard, 2014).

It is necessary to keep in mind that benchmarking is not a one-time event but an ongoing process for achieving and sustaining improvement. Flexibility, adaptability, and a commitment to change are essential for successful benchmarking.

A prioritization matrix, also known as a decision matrix or a criteria matrix, is a tool used to help make decisions by ranking options based on multiple criteria. It is particularly useful when faced with a complex decision that involves many factors that need to be considered.

Prioritization matrix

Due to the optimal setting and selection of postures, we had to set the preferential values of their selection. Since the company has 1255 mechanisms, this process was necessary. We used a method to select the prioritization matrix, which is created by listing all the criteria that are important for making the decision and assigning a weight to each criterion, reflecting its relative importance (Derkawi, 2023). Then, the options being considered are listed along the top of the matrix, and each criterion is evaluated for each option and given a score. The scores are then multiplied by the weight of each criterion and added up to give a total score for each option. The option with the highest total score is considered the best option (Berkun, 2005).

We assign a weight to each criterion based on its importance, with fuel efficiency being the most important, safety rating being moderately important, and price and design being less important. We then evaluate each car based on each criterion and give it a score, such as a rating out of 10. The scores are then multiplied by the weight of each criterion and added up to give a total score for each car. The car with the highest total score would be the best option. The prioritization matrix is a useful tool for decision-making because it allows us to consider multiple factors and weigh them according to their importance, leading to a more informed and objective decision.

Results

The company achieves a high degree of internationalization. According to the internationalization approach, the concern actively seeks new opportunities, directly manages foreign operations, is massively active in foreign markets in the form of direct investments, and does business in many world markets that are quite different from each other. The company operates in selected markets in Europe, the United States of America, and Latin America. It currently employs 52,000 employees, including approximately 5,600 employees in the Czech and Slovak Republics. Its shares are traded on the stock exchange. The company has a wide portfolio of activities. The entire concern is divided into four main areas, which are construction, residential development, commercial development, and infrastructure. As we wrote above, within the company, we will look for a benchmark regarding the best parameters within the machines located in the quarries. The company needs to find out which of the subsidiaries could serve as a model example for improving the parameters and even the convergence of the others. A very interesting part is also the environmental component, which is also monitored by the company to reduce the burden on the environment with exhalations, and the company wants to find out which company has the idlest engine hours. The following groups of machines were selected from the overall list, taking into account their work directly in the quarry. The data obtained from the company for selection and processing for the calendar year 2022,

as determined periods due to the pandemic, were not relevant enough. Based on the pandemic period, we were not able to objectify the information, as the year 2019-2021 was within the standard because the company was partly closed due to the situation with COVID-19, and from this point of view, the data was not sufficiently relevant for processing. The year 2022 was the first in which it was possible to realistically evaluate consumption and moto hours, as the operations worked without restrictions during the entire monitored period (Derkawi, 2023). In the chosen countries, we select a group of excavators over 35T.

A tracked excavator differs from a typical excavator due to the added tracking system instead of wheels on most excavators. The purpose of the steel tracks is to provide the excavator with further resistance and grip on the surface they are operating on. Tracked excavators, also known as crawler excavators, are heavy equipment machines commonly used in construction, mining, and other industries for digging and excavation tasks. They are designed with tracks or crawlers that provide stability and mobility on rough terrain, allowing them to operate in various conditions. Tracked excavators are typically equipped with a long, articulated arm or boom that is attached to a bucket at the end. The arm is operated by hydraulic cylinders, allowing the operator to move the bucket in a wide range of motions and to dig deep into the ground. The bucket can also be swapped out with other attachments, such as a breaker or grapple, to perform other tasks. Often referred to as cranes or hoes, a track excavator is a common piece of equipment when digging large holes. There are many uses for a track excavator. Digging ditches and basements, demolition, and breaking up structures are just a few. Table 1 describes the devices located in the studied countries as well as their average consumption in terms of engine hours.

Tab. 1. Tracked excavators over 35T *based on (Derkawi, 2023)*

Country	Producer	Type	Engine power (kW)	Average consumption (l/wh)
SK	CATERPILLAR	345	239	22,40
CZ	CATERPILLAR	336D LN	210	22,29
CZ	VOLVO	EC360CL	190	19,49
CZ	VOLVO	EC460BLC	230	17,23
CZ	KOMATSU	PC350LC-8	220	20,82
CZ	KOMATSU	PC350LC-8	235	
CZ	VOLVO	EC380DL	208	16,08
HU	CATERPILLAR	385CLME	395	51,83
PL	CATERPILLAR	336E	240	25,04
CZ	VOLVO	EC380EL	208	22,07
CZ	VOLVO	EC380EL	208	20,45
CZ	VOLVO	EC380EL	208	18,53
PL	CATERPILLAR	340F LME	230	22,69
CZ	VOLVO	EC380EL	208	16,23
RO	CATERPILLAR	336FL	235	29,40
HU	VOLVO	EC480DL	256	24,29
CZ	VOLVO	EC480DL	265	20,27
CZ	VOLVO	EC480DL	278	25,75
HU	VOLVO	EC480DL	278	20,82
HU	VOLVO	EC480DL	278	27,83
RO	CATERPILLAR	352F	311	39,04
SK	CATERPILLAR	352 NEXT GEN	316	29,70
PL	VOLVO	EC750E	384	51,16
HU	CATERPILLAR	390FL	405	53,86

Figure 2 shows a comprehensive summary of triple devices by manufacturer and ends with the cumulative number of single machines.

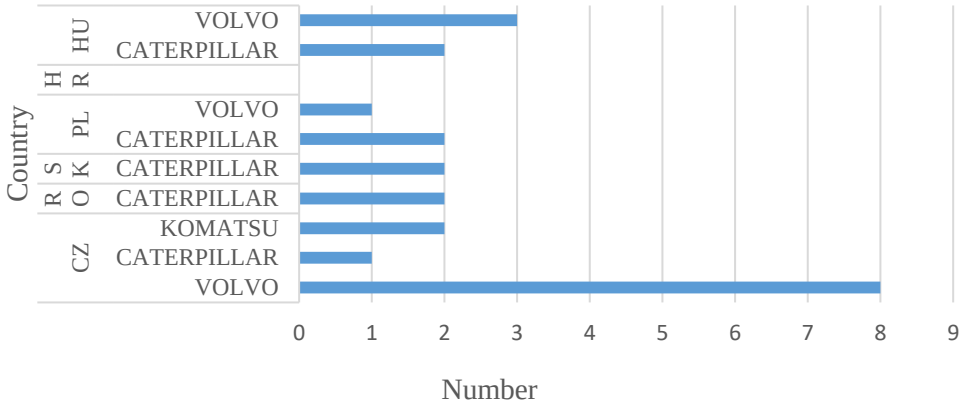

Fig. 2. Number of tracked excavators by manufacturer per country based on (Derkawi, 2023)

In the case of tracked excavators, we set priority areas for benchmarking evaluation. Among the investigated companies, we selected three that were important to us in terms of data complexity, and the vehicle fleets were interesting due to their wide range, see Figure 3.

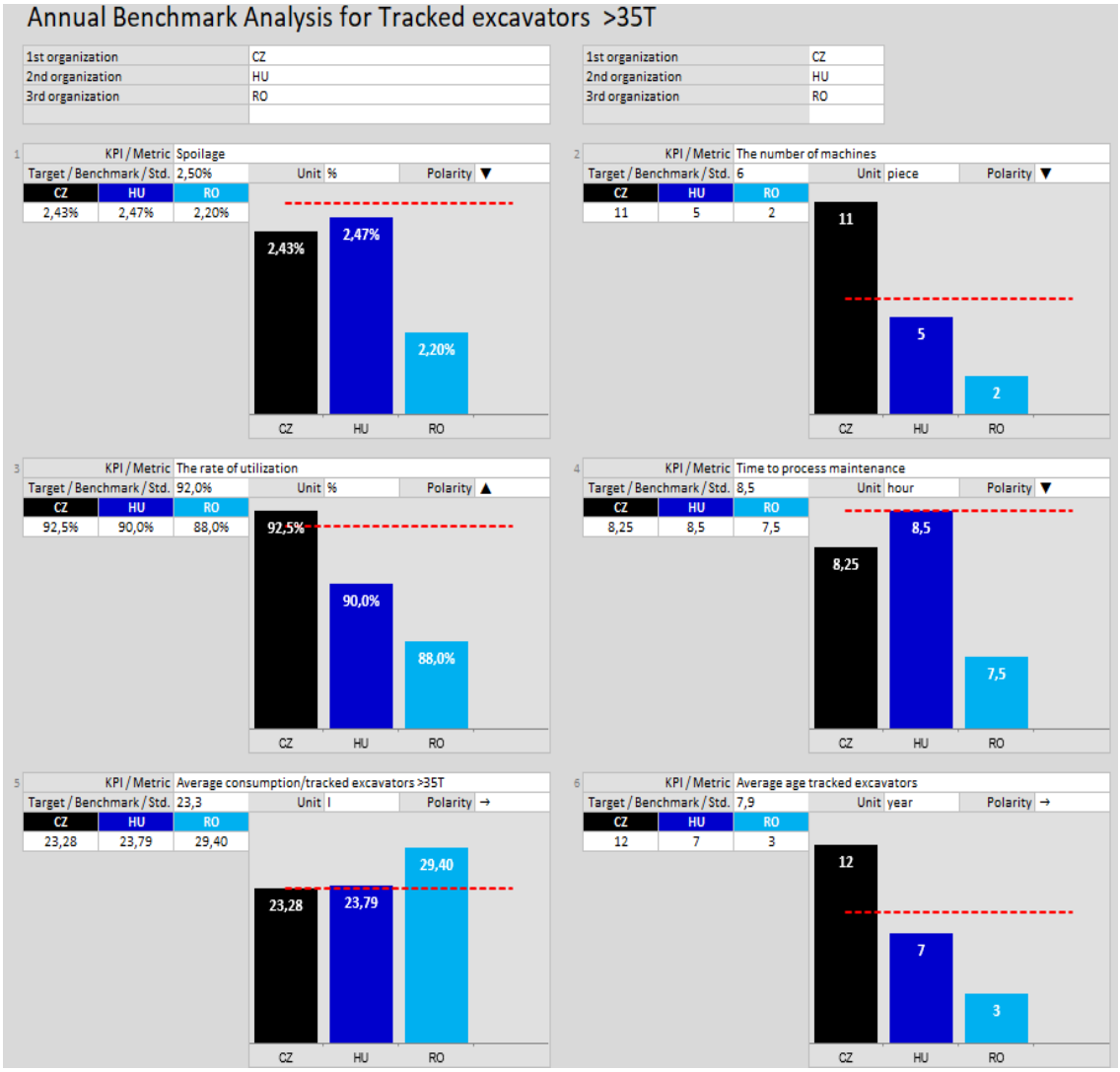

Fig. 3. Benchmark analyses for selected countries based on (Derkawi, 2023)

For tracked excavators, we used items such as the average consumption for the given stationary equipment in the global of all participating countries, as this total value reflects more accurate values, which gives us a better perspective on the reality of the consumption of individual machines. Another important component for us was the age of the self-heating equipment, as it affects consumption and the necessity of shutdowns due to unrefined repairs, which costs much money. Subsequently, we also took into account the actual service routines, as mentioned above, they are performed every 250 moto hours. One of the monitored areas was the utilization of the given devices, mainly due to the correct setting of the number of devices. Within the internal processes, the variables must be unified, as it speeds up the benchmarking process, and it is then more efficient both from the point of view of human resources and also concerning costs. Based on the findings, countries that did not have all the necessary data were eliminated from the group of subsidiaries of interest, as benchmarking would not be suitable for them. In this case, when all relevant information is not fully represented, it is necessary to completely exclude countries like Croatia, Poland, and Slovakia from the benchmarking. Due to the fact that, after a detailed analysis, we had sufficiently mapped the individual quarries in the countries and their equipment, the overall summary was much more effective. From the data we processed, after the basic evaluation, we had to eliminate countries that did not meet all the variables entering the process. As part of the internal benchmarking, we revealed the biggest weakness in the investigated companies. A problem area that significantly affects costs and potential return is in the area of Downtime reduction. Based on the analyses, we have come to findings that show that reducing the time during which the equipment is not performing work could reduce costs in several areas. The causes are different, but the primary source is the human factor. In principle, for various reasons, machinists do not turn off the equipment, and even when they are not working, the equipment is in on mode. From our point of view, it was necessary to exclude these countries, as they would distort the overall process and course of benchmarking. In our case, it was items like Reducing the time when devices go empty. This activity is monitored by telematics, which is a system for collecting operational data. Telematics collects information and data for GPS monitoring, consumption, engine speed, error messages, and others. Based on this information, it is possible to predict the overall condition of the machine as well as its optimal use. If we would like to point out the consequences of this activity, they are as follows:

- leads to increased maintenance costs, as the system is set for maintenance of 250 motor hours, and in this case, it is earlier than the real equipment would achieve this time under a reasonable workload,
- the selling price is reduced, taking into account the condition of the watch and the life of the device, and costs associated with consumed fuel would be reduced.

Conclusions

Any unexpected change, especially of a negative nature, can cause big problems for the company, especially if it had no idea that the given change could happen. After the implementation of benchmarking, the management of the organization should deal with the evaluation of the real benefits of benchmarking (even in comparison with the efforts and costs) and decide on the continuation and further use of the benchmarking method in the management of the improvement of the organization and its managed area. The task of managers is to look for procedures and methods that will help the company detect most of these changes and support managers' decision-making in key situations for the future of the company itself and its employees. Thus, benchmarking is a universal method. Its various types mutually supplement each other, making it one of the most effective enterprise performance management methods. As noted above, a variety of benchmarking lies in its types, which allow the improvement of various aspects of the enterprise due to different sources of improvement. In our opinion, the main objective of performance management is to ensure continuous and sustainable growth of enterprise performance. In conclusion, benchmarking is a powerful tool for organizations to evaluate their performance, learn from the best, and drive positive change. The conclusions drawn from benchmarking can guide decision-making, enhance operational efficiency, and contribute to long-term success in a competitive landscape. Businesses that compare their behaviour with others and identify best practices are more able to gain strategic, operational, and economic benefits by improving their operating regulations and processes. Companies could help each other based on the information provided, and their enforcement in the after-sales markets would also be more effective. Sharing information about environmental protection technologies or work efficiency will not hurt the competition, but it will help motivate the market participants to perform even better, ultimately significantly affecting the customer.

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