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ANALYSIS, PRACTICAL APPLICATION AND POSSIBLE INTERCONNECTION OF INDUSTRIAL ENGINEERING METHODS AND KEY PERFORMANCE INDICATORS

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Abstract: In connection with applying the principles of Industry 4.0, the industrial practice also requires the consistent application of industrial engineering methods to improve process performance. The transformation of society into digital affects almost all areas of industry, public administration, healthcare and all walks of life. The implementation of Industry 4.0 is very important in the automotive, engineering and electrical engineering industries. It is the move towards Industry 4.0, the collection of large amounts of data and the decision-making based on the data obtained that provide the ideal basis for using more complex industrial engineering methods and better process evaluation.
The paper's main goal is to analyse and identify the use of industrial engineering methods and key performance indicators of companies in industrial practice in Slovakia, where practice shows a lower acquaintance with these methods, especially among medium-sized companies. The paper deals with the issue of industrial engineering methods aimed at improving process performance in the context of key performance indicators. The paper contains some results of a questionnaire survey aimed at gathering information on improvement methods and identifying the use of key performance indicators in industrial practice. Which results will bring us closer to which types of methods are most used in Slovak practice and why?

1 Introduction

Today's modern technologies contribute to performance and productivity and have also taken over some of the activities in the production process. In modern companies that have implemented Industry 4.0 technologies and use highly automated machines and equipment in production, these machines have replaced people in selected parts of production. Production workers only operate the machine, which is a characteristic element of the fourth industrial revolution. Thus, Industry 4.0 is characterised by interactions and communication between machines and cyber-physical systems for real-time operations management [1].

The main idea of industrial transformation is to increase competitiveness by increasing enterprises' efficiency and productivity. Companies can achieve this goal under the conditions of monitoring and subsequent improvement of the performance of the processes taking place in the system, improvement of the quality of processes and elimination of discrepancies in the production system [2].

There are many methodologies and industrial engineering methods aimed at improving process performance. The paper's content is the analysis and use of industrial engineering methods in conjunction with Key Performance Indicators (KPIs) in industrial practice. We investigated the actual state of use of methodologies and methods of industrial engineering in industrial practice in order to improve process performance, increase quality and eliminate deficiencies. Using a questionnaire survey, we found out the state of use of industrial engineering methods in practice and at the same time, we want to draw attention to the real state of use of methods and methods of industrial engineering in practice, and also using KPIs to measure and analyse data in companies.

Businesses must maintain or improve competitiveness to analyse activities and processes using data within the production system. They can also obtain this data using KPIs and then evaluate it and suggest improvements using the given industrial engineering methods.

1.1 Theoretical connection of industrial engineering methods and KPI

Process improvement is an activity that specifically focuses on analysing process behaviour, identifying the causes of problems related to process continuity and also focuses on process quality, efficiency, and productivity. Process improvement is based on the current process, depending on how the process is documented in the documentation or according to the knowledge of the process participants [3].

The starting point for improving the efficiency of production processes and the overall production system of the company is the optimal setting and use of production factors. Factors arising from the need to meet all customer requirements and adapt to the changing conditions of the company's environment (e.g. increasing competitiveness, reducing costs, or increasing the overall flexibility of the company) are important. The aim of these business activities is to achieve measurable economic and production results, such as the efficiency of the production process and timely performance of tasks, identification of factors affecting not only product quality but also shortening inter-operational times, minimising inventory. Advanced methods of industrial engineering and management of production processes in the company play an important role in improving existing production systems and eliminating errors [4].

Process management in an industrial enterprise is applied not only at the level of production but also in logistics, customer service, etc. All these processes and activities must be coherent and coordinated at a high level in order for the company to be efficient in production, respectively in services. Some processes and their management are taken care of by artificial intelligence thanks to the advent of Industry 4.0. All processes in business practice are measurable and analysed with technologies and elements of Industry 4.0 in real-time. Processes can be measured using indicators such as productivity indicators (OEE), economic (profit, cost, profitability), qualitative (FPY, complaints, scrap), time (clock time, cycle time). These indicators are analysed in companies using various methodologies, methods, tools, techniques of industrial engineering. At present, a number of different methods and tools are described in the scientific literature, which is used in improving processes in business practice, e.g. simple quality management tools, various statistical methods, value flow mapping, SMED, TPM, bottleneck theory, and methodologies such as Lean management, Six Sigma and more. In fact, it is worth noting which of these methods of improvement will be effective even in conjunction with technologies and elements of Industry 4.0 [5,6].

By introducing Industry 4.0 technology into business practice, new processes are expected to be created. These processes will involve more technology and be smarter, but they will remain processes. These future processes will still create space for the use of Six Sigma and other methods, respectively, improvement methodologies. Processes will continue to require analysis, the definition of capabilities, control to be effective and efficient, but they will also require information and the definition of new parameters that will affect them. With increasing automation and the potential to mass produce unique products, automation processes should collect more data and be faster in real-time. There will be a lot of overflow of data and information about the processes, which will need to be sorted according to the importance of the parameters at a given time [7].

New technologies bring a new era of business, new approaches to business operations, as well as new jobs that require new competencies and skills of employees. While new jobs will require new knowledge and skills, the right combination of skills needed to perform in modern industrial enterprises is becoming more complex and will continue to evolve with the development of a technologically advanced work environment. This will require future generations of workers to develop their digital skills and build access to lifelong learning [8].

Process performance can be defined as the extent to which a process result is able to meet the requirements of internal or external customers of the process. Within a company as a system of different departments, interconnected material and information flow, and complex process chains, the performance of a particular process cannot be measured independently. In this context, the interdependencies with the delivery procedures at the beginning of the delivery, failures, and the setting of control variables or parameters are important impact factors that need to be taken into account when evaluating process performance [9].

The new parameters will be measured by built-in sensors on machines equipment. Examples of parameters are temperature, speed, pressure, rotation, etc. This is precisely the space for the development of the Six Sigma methodology, which can develop a lot of data and information and analyse this data in the repository, but also the space for the development of other methods and the implementation of advanced industrial engineering methods in practice. Thanks to Industry 4.0, such as Big Data, methods and methodologies will be developed based on the measurement, analysis, and application of statistical tools and techniques. Current statistical tools and techniques will increasingly find their use, and it is likely that new techniques and tools will emerge to focus on statistical management and quality control of new processes. New tools and methods will emerge, but current methods such as DMAIC, PDCA cycle, Pareto analysis, or Ishikawa diagram will still be used. Most of the methods and tools used in the Six Sigma methodology will continue to be used, and it will still be necessary to understand the causes of problems and address problems. Future machines and equipment will take control of the processes individually or in cooperation with statistical control, real-time analysis, and autocorrection [10].

The development and implementation of key performance indicators (KPIs) methods support manufacturers by quantifying processes, identifying potential vulnerabilities, and evaluating and comparing them. KPIs focus on key aspects of the performance of the assessed fact/process. They are part of a family of key indicators divided into two main groups, namely performance indicators and result indicators. These quantifiable and strategic measures are essential for understanding and improving production performance, both in terms of eliminating waste and achieving the strategic goals that are most important for current and future success. Based on industry principles for evaluating technology, KPIs support the comparison of different processes and their results within the manufacturing industry. KPIs are those indicators that focus on aspects of an organisation's performance for which the organisation's current and future success is paramount [11].

Performance indicators, which can be defined as information collected at regular intervals to monitor system performance, are the basis for evaluating and comparing the performance of processes across enterprises. Through ratios and metrics, and measurements, they help control processes by making it possible to compare planned and achieved results. Different approaches are used to classify process performance indicators. For example, there are classifications by service dimensions (process, potential, and outcome), performance dimensions (quality, cost, time, customer satisfaction, flexibility), or by supply types (e.g. maintenance, planning, repair). Such classifications help define performance indicators suitable as metrics for analysis and control with a special focus on specific aspects [9,12,13].

Indicators, in general, need to be distinguished by absolute numbers and relative numbers. Absolute numbers are independent of other indicators. They contain an individual number, sum, difference, and average. They gain importance only by comparison with other indicators. In contrast, relative numbers combine information, e.g. indicators through ratios [14].

The relative number can be divided into quotas, reference numbers, and index numbers. Quotas are a ratio of one indicator to the whole, and important indicators can therefore be compared. Reference numbers are the ratio of the same indicators with different contents. Last but not least, index numbers compare time series. Thus, the literature focuses more on financial KPIs and less on non-financial ones. Important non-financial KPIs are productivity, quality, time, and intangible assets. Nevertheless, it is possible that a company will comprehensively obtain information about business problems only by considering financial and non-financial KPIs.

Appropriately selected and set KPIs meet the conditions of SMART, so they are measurable, unambiguous, understandable, set according to real facts, and limited in time. The time limit in the case of KPI represents the frequency of measurement and evaluation of a given indicator [15].

2 Methodology

Using methods of improvement, companies improve, among other things, competitiveness, innovative production processes, and product quality. In order to be able to use the methods of improvement, they need to obtain data within the production system and the actual performance of the company. They can also use KPIs to obtain this data from the production system. The use of these KPIs is important as well as the use of industrial engineering methods. The actual state has ascertained the use of methods and methodologies of industrial engineering and the use of KPIs through a questionnaire survey.

The questionnaire survey was focused on medium and large companies, while in 2020, when the survey was conducted, there were 1344 companies in Slovakia. Most of the companies involved belong directly to the automotive industry or are suppliers to the automotive industry. Two hundred and thirty-six companies were contacted with a request to fill in an online questionnaire. Sixty-four enterprises participated in the questionnaire survey, of which 68.7% were medium-sized, and 31.3% were large enterprises. Due to the small variability in the area of their operation, it was decided not to distinguish between the individual sectors in which companies operate for further work with the results of the questionnaire. Table 1 shows the percentage of enterprises by nature of production and size of the enterprise. Medium-sized companies with serial production had the largest share. The future research will be primarily focused on this type of company.

Table 1 Nature of production due to the size of the company (own processing)

Company size and nature of production		%
Medium enterprise	Pride production	23.44%
	Batch production	40.60%
	Mass production	4.69%
Large-scale enterprise	Pride production	4.69%
	Batch production	17.19%
	Mass production	9.38%

3 Results and discussion

Respondents to the question *"What methods or do you use industrial engineering tools to improve the company's*

processes?". This question was opened without a choice, and therefore, the participating respondents mentioned the Six Sigma option. As part of our research, the issue of Six Sigma is classified as a comprehensive improvement methodology, which is why the DMAIC was assigned to Six Sigma.

Table 2 shows what industrial engineering methods and tools to improve processes and their performance are used in a sample of companies operating in Slovakia. The chosen criterion for identifying the parameters of use was the size of the company. Based on this criterion, Table 2 shows the structure of the use of these methods in medium-sized enterprises (blue) and large enterprises (red). The most common answer for medium-sized companies was that "they do not use any methods, or tools "as part of improving business processes (up to 15% of companies gave this answer). This fact is a negative finding in business practice in Slovakia. The answer was that they could not name the method, and the results say that if they use the methods, they do not know about them, as they do not even know how to name and define them. This was followed by methods and tools that he considers simple and has only partial positive results in improving processes when used individually without a defined methodology. In the case of medium-sized companies, it was found that companies do not use the Six Sigma methodology, or DMAIC procedure, which was the most common answer in a group of large companies.

Table 2 Use of methods and tools of industrial engineering within a sample of companies (own processing)

Methods and tools of industry engineering	Medium enterprise	Large-scale Enterprise
We do not use any methods	15.3%	1.2%
5 S	7.1%	2.4%
We can not name it	11.8%	0.0%
Ishikawa diagram	4.7%	4.7%
PDCA	3.5%	3.5%
DMAIC / SIX SIGMA	0.0%	9.4%
Kaizen	3.5%	2.4%
8D	3.5%	2.4%
TPM	2.4%	3.5%
TQM	1.2%	1.2%
5x why?	1.2%	2.4%
SMED	0.0%	1.2%
Brainstorming	3.5%	1.2%
VSM	1.2%	4.7%
Analysis of customers requirements	0.0%	1.2%

The Six Sigma method was included in the DMAIC procedure in the answers, i.e. as a comprehensive improvement method. Individual methods and industrial engineering tools are used for process improvement. None of the addressed medium-sized companies does use the Six Sigma method or the entire DMAIC process, as well as the SMED method and the Customer Requirements Analysis.

The questionnaire was focused on the use of KPIs, and these results are shown in Table 3. The survey shows that the concept of key performance indicators is widely used in large companies and companies defined as a medium. Only 4.3% of the participating medium-sized enterprises do not use any key indicators. However, it should be noted that the automotive industry, together with its suppliers, in Slovakia is most closely connected with foreign companies, in which key indicators have been used for a long time. Therefore, for industrial enterprises in Slovakia focused on other industries, the use of KPIs may differ depending on the industry.

Table 3 Use of KPIs in business practice due to the size of the company (own processing)

Used KPI	Medium enterprise	Large-scale Enterprise
Productivity, efficiency	21,5%	15,2%
Economic	12,7%	10,1%
Quality, confusion, KPI	11,4%	8,9%
Time	10,1%	7,6%
Do not use	2,5%	0,0%

Another interesting finding when using key indicators is the percentage distribution of these groups of indicators, which are shown in Table 3. The area of productivity and process efficiency was found that the area where key indicators are most used, with 37% of medium-sized enterprises using these indicators and 36.4% of large enterprises. The most frequently reported productivity and process efficiency indicators were overall equipment effectiveness (OEE), productivity index, and internally determined productivity indicators in the company. The quality of processes is also closely related to productivity and process efficiency. For example, the addressed company states the common measurement of customer satisfaction, confusion, and the ratio of nonconforming products to the total number of products produced. Given this fact, it is assumed that industrial engineering methods, which are closely related to the efficiency of the process, whether in their design or later elimination of the identified shortcomings, thereby also contributing to improving the

quality of processes and their outputs, will be a suitable platform for the implementation of key indicators.

Research has shown that Six Sigma is used in large companies. However, the results by medium-sized companies are stated little interest in the use of Six Sigma as part of the initiative to improve processes and product quality continuously. In the near future, even small and small businesses are expected to be forced to use the Six Sigma methodology, primarily those that act as suppliers to large global companies. The Six Sigma methodology offers a large number of radical improvements in the quality of processes and products, which leads to increased competitiveness, the company's improved financial performance, customer satisfaction, and an overall improvement of the company's results.

The question is why medium-sized companies do not use the Six Sigma methodology. This is assumed to be due to ignorance of the methodology, low awareness of the methodology, insufficient knowledge of employees about the methodology or overall application documentation, and the use of statistical tools and methods, respectively, industrial engineering methods within the given methodology. These facts will be investigated further in our work and focus on the problems of implementing the Six Sigma methodology.

Based on the perceived greater interest in the Six Sigma methodology by medium-sized companies, which generally have less insight into not only the methodology itself but also other methods of industrial engineering, as well as the fact that modern technology gives business managers access to fast and precise information, which requires the need for appropriately selected methods of measuring and evaluating business processes. In the Six Sigma methodology as well as in the application of other methods of industrial engineering is anticipated a wide possibility of applying the philosophy of key indicators.

Through research, in the application of methods to improve performance, respectively improving the quality of processes and products themselves were founded that due to the company's size, there are obvious differences between medium and large companies in industrial practice in Slovakia.

4 Conclusion

Technological progress is constantly advancing, and nobody knows what to expect in the next decade, which will bring the Industry 4.0 paradigm. The Industry 4.0 concept is adopted by companies and implements individual technologies that ensure the company's competitiveness. The competitiveness of companies will be ensured by new technologies and the use of individual methodologies, methods, or tools to improve the quality of products, processes, and services. Because companies know how to measure and evaluate a given quality, key performance indicators - KPIs are used. The main goal of this paper was to identify and analyse the use of industrial engineering methods and key performance indicators in industrial practice in Slovakia. The paper dealt with the issue of industrial engineering methods aimed at improving process performance in the context of using key performance indicators. This paper is dealt with the analysis and evaluation of a questionnaire survey focused on the use of improvement methods and the identification of KPIs in industrial practice. The research concluded that only some methods are used in individual companies to improve processes. Still, very few Slovak companies use the methods of improvement as a whole within the given methodology. Based on the findings, it is emphasised that methods aimed at improving processes must be used as a set of methods in applying the methodology, such as Six Sigma. It is necessary that within the applied methodology, there is a connection between measurements and performance evaluation using KPIs.

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References

[1] SHROUF, F., ORDIERES, J., MIRAGLIOTTA, G.: *'Smart Factories in Industry 4.0: A Review of the Concept and of Energy Management Approached in Production Based on the Internet of Things Paradigm.'* Proceedings of the 2014 IEEE International Conference on Industrial Engineering and Engineering Management. IEEE, pp. 697-701, 2014. https://doi.org/10.1109/IEEM.2014.7058728

[2] POTKÁNY, M., GEJDOŠ, P., LESNÍKOVÁ, P., SCHMIDTOVÁ, J.: Influence of quality management practices on the business performance of Slovak manufacturing enterprises, *Acta Polytechnica Hungarica*, Vol. 17, No. 9, pp. 161-180, 2020.

[3] SVOZILOVÁ, A.: *Zlepšování podnikových procesu*, Praha, Garda Publishing, 2011. (Original in Czech)

[4] FREY, C.B., OSBORNE, M.A.: The future of employment: How susceptible are jobs to computerisation?, [Online], Available: https://www.oxfordmartin.ox.ac.uk/downloads/academic/future-ofemployment.pdf [15 Nov 2021], 2013.

[5] DARON, M., GÓRSKA, M., DUNAY, A.: *'Improvement of the production system functioning with using quality management tools in the metallurgical enterprise.'*, MATEC Web of Conferences, Vol. 183, pp. 1-6, 2018. https://doi.org/10.1051/matecconf/201818303016

[6] GAJDZIK, B.: World Class Manufacturing in metallurgical enterprise, *Metalurgija*, Vol. 52, No. 1, pp. 131-134, 2013.

[7] PUGNA, A., NEGREA, R., MICLEA, S.: Using Six Sigma Methodology to Improve the Assembly Process, *Procedia – Social and Behavioral Sciences*, Vol. 221, pp. 308-316, 2016.

[8] European union, www.europarl.europa.eu: Industry 4.0, [Online], Available: https://www.europarl.europa.eu/RegData/etudes/BRIE/2015/568337/EPRS_BRI(2015)568337_EN.pdf [15 Nov 2021], 2015.

[9] MEIER, H., LAGEMANN, H., MORLOCK, F., RATHMANN, C.: *'Key performance indicators for assessing the planning and delivery of industrial services.'*, 2nd International Through-life Engineering Services Conference, pp. 99-104, 2013. https://doi.org/10.1016/j.procir.2013.07.056

[10] GIJO, E.V., SCARIA, J.: Process improvement throught Six Sigma with Beta correction: a case study of manufacturing company, *International Journal Manufacturing and Technology*, Vol. 71, No. 4, pp. 717-730, 2014. https://link.springer.com/article/10.1007%2Fs00170-013-5483-y

[11] DORN, C., BEHRENDA , R., GIANNOPOULOSB, D., NAPOLANOC, L., JAMESC,V., HERRMANNA, A., UHLIGA, V., KRAUSEA, H., FOUNTIB, M., TRIMISD, D.: *'A systematic LCA-enhanced KPI evaluation towards sustainable manufacturing in industrial decision-making processes. A case study in glass and ceramic frits production.'*, 23rd CIRP Conference on Life Cycle Engineering, Vol. 48, pp. 158-163, 2016. https://doi.org/10.1016/j.procir.2016.03.146

[12] TONN, K.: *Lean-Service: Ein ganzheitlicher Ansatz für die Erbringung industrieller Dienstleistungen*, Aachen: Shaker, 2012. (Original in German)

[13] FINKE, G., WANDFLUH, M., HERTZ, P.: Leistungsmessung Industrieller Services: Auf welche Leistungs-Dimensionen kommt es an?, *Industrie Management*, Vol. 29, No. 1, pp. 19-23, 2013. (Original in German)

[14] HERMANN J.: *Kennzahlbasierte Planungsmethode zur Optimierung der Anlagennutzung von Großpressen*, Auerbach/V: Verl. Wiss. Scripten, 2013. (Original in German)

[15] LANGE, I.: *Leistungsmessung industrieller Dienstleistungen: Prozessund Leistungstransparenz als Basis für das management von Produkt-Service-Systemen*, Zürich, Dissertation, 2009. (Original in German)

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