Article

A System for Supporting the Selection of Progressive Methods and Technologies with the Aim of Improving the Management of Production Processes

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Abstract: Managers are often faced with the task of improving the management of the production process in order to maintain the sustainability of production efficiency in a highly competitive environment. The submitted contribution deals with the design of a system that will support them in the selection of progressive methods and technologies in order to improve the management of production processes. Managers often follow new trends in this issue, but it is not easy to work on the knowledge that proven progressive technologies can bring them higher efficiency. The presented system is based on the use of knowledge of existing solutions of manufacturers of automotive components, where companies solve similar problems in production management. The mix of methods and technologies used in the management of production processes brings companies different results in the achieved efficiency. The proposed system for supporting the selection of the production management method and technology is designed from blocks of data collection, benchmarking of the performance of production processes of industrial enterprises, further from data mining technology to obtain knowledge about the effect on efficiency from already implemented technologies. The last blocks help to examine the differences in the implementation of the same methods and technologies and allow to present the obtained results to the manager in the form of recommendations for choosing a suitable progressive method and technology.

Keywords: management methods; management; system; technologies; production process; process improvement

1. Introduction

At present, it is not a relatively difficult problem to collect large amounts of data and information that describe the company's current processes. Today, data, information, and knowledge are strategic sources for further business development. It often happens that the collection of information is a priority, but only afterward is its meaning and reason for analyzing it and turning it into knowledge.

Companies monitor the development of new technologies and often wonder if the time is right to reassess the state and benefits of current technologies. These are mostly investment decisions that may affect the future of the company for several years to come. Therefore, they pay great attention and time to such a decision. From the point of view of production process management, it can be stated that investing in change is not always a

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question of financial costs but a high share is also played by the correct choice of the appropriate method or technology, which in each company is influenced by important factors. As a result, companies are trying to implement the latest methods and technologies for production management on their own or in cooperation with consulting companies, which in the end do not result in the expected and promised benefits.

The authors try to eliminate this problem by designing a system that, based on the information provided by the participating companies, would help to recommend a proven solution with clearly declared benefits from the use of selected methods and technologies in production management.

The system for supporting the selection of progressive methods and technologies uses benchmarking, which will provide information about existing solutions in production management in individual production segments. The best solutions are classified by self-evaluation of the achieved change after applying a new method or technology for the management of production by the company.

The degree of success of a particular method or technology in the management of production processes in the company and its numerous representation makes it possible to analyze data mining technology. According to the obtained results in the specific segment where the company is included, the management can make a decision to invest in the recommended technology for management to ensure the sustainability of production efficiency in a highly competitive environment.

The result of the decision is based on the known achieved results and the company can follow the steps of the best in applying the same methods and technologies.

The aim of the article is not to point out which solutions are currently the best, but to present a tool, a system that can help them to avoid using the trial-and-error procedure, which costs a lot of money.

The expected result of the presented proposed system is obtaining the best solutions for the management of production processes. The resulting choice of methods and technologies in the same production segment should offer satisfactory or better results in the given segment than the company currently achieves in the efficiency of production process management.

2. Methods

Various research methods have been used to research the topic:

- Questionnaire - used to determine the current state of use of methods and technologies supporting the management of production processes by companies in Slovakia.
- Interview - in the company TC CONTACT s.r.o. in Nové mesto nad Váhom a structured interview was conducted with manager Ing. Tetiana Telecka.
- Classification - classification of the company according to defined characteristics into segments.
- Benchmarking - comparison of the achieved performance of production companies and search for the best of the best company in the given segment.
- Mathematical and statistical methods:
- Correlation analysis - monitoring the level of dependencies of performance indicators and the methods and technology used.
- Decision tree classification - data mining.
- Analysis - literature, the current state of logistics strategy.
- Synthesis - results of analyzes of the external and internal environment.
- Induction, deduction.

3. Literature review

3.1. Production process management

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Production management is an integrated part of the company's management system. The main goal of production management is to increase productivity, and compliance with time and volume requirements while maintaining the quality and economy of production with the effective use of production equipment of the company. [1]

In addition to market requirements, manufacturing companies must respect the development and direction of technologies that offer a rapid leap in the management of production processes. Classic approaches to managing production process planning include methods from the second half of the last century. During this period, the philosophy of JIT (Just-in-time), MRP (Material Requirements Planning), MRP II (Manufacturing Resource Planning), and TOC (Theory of Constraints) was created [2].

3.2. Methods and philosophy of production management

MRP (Material Requirement Planning)

In the 1960s, a method was born in the United States that focused on material inventory planning rather than production planning and control. This production operational management tool has been named MRP (Material Requirement Planning) and its main benefit is planning based on the existing need to produce a product. This need arises from the order received or from the forecasts and expectations of the sales department about future developments in market requirements. The benefits of MRP are also that it ensures that the right material is in the right place at the right time and in the right amount [3].

The MRP method plans the ordering of material and production not only in the required quantity but also about thein required for delivery or production of components. The method assumes the most accurately determining value of the continuous times of production and delivery of the ordered material. However, these values are often higher than would be required. On the one hand, they thus defend against unexpected negative events, on the other hand, inaccurately determined times prolong delivery times [4].

TOC (Theory of Constraints)

The origin of TOC (Theory of Constraints) dates back to 1984 when it was described by Israeli physicist Eliyahu Moshe Goldratt in his managerial novel The Goal. The theory of limitation is based on the finding that every company, regardless of the area in which it operates, has a bottleneck. A bottleneck can take many forms, such as one particular production machine, improper business organization, improper supply chain, and the like. If the bottleneck did not exist, the company would have unlimited possibilities and could produce an infinite number of products or services [5].

According to the TOC, the main goal of the company is to make money now and in the future - "Make money now and in the future". It also follows that costs should not be reduced at present if this could have adverse results in the long term. Various measurement and evaluation tools are used to determine the fulfillment of this goal. The classic ones include net profit, ROI (Return On Investment), and cash flow. Constraint theory adds additional measurements of flow, inventory, and operating costs. Throughput refers to the money that a company receives from the sale of its products and services, less the price of variable costs. Inventories include all money for which the enterprise has purchased materials consumed in production. Operating expansion is the money needed to turn inventory into the flow. From a constraint theory perspective, inventory and operating costs are required to be minimized and flow maximized, with an emphasis on maximizing flow. It is the size of the flow that is limited by the bottleneck. It follows that the time gained before the bottleneck is of zero value to the company and the time lost in the bottleneck is the loss of the whole system. It is also true that improving a non-bottleneck will not bring any improvement to the business. Only by eliminating the bottleneck or widening it will the flow increase until it encounters another restriction [5].

OPT (Optimized Production Technology)

The starting point of the OPT system is the consideration that the emerging bottlenecks have a significant impact on the production process. The push-pull principle is applied here. It is undoubtedly a successful production planning and management system. He is one of the representatives of departmental centralized production planning and management systems. The OPT system was first built by an Israeli physicist and also a prominent figure in production management, E. M. Goldratt. According to him, the basis of OPT is common sense and the thesis "Let people do the right things". It can be stated that this system has been successfully implemented in many Western companies. The initial consideration is that the identification and optimal occupancy, resp. By using narrow capacities, an improvement in the average utilization of all production facilities, a reduction in average times, as well as a reduction in the number of employees can be ensured [6].

OPT, therefore, focuses primarily on bottlenecks, which are a crucial prerequisite, respectively. The key is toincreasinge the overall output of the business unit.

DBR (Drum Buffer Rope)

DBR is a bottleneck management system. The DBR system provides a set of practical procedures to eliminate the problem of dynamic bottlenecks in production using the push principle. This system was developed within the OPT method as a practical system of workshop production management. The method belongs to the area of flow synchronization. It is based on the idea of creating a buffer in front of the bottleneck, which ensures its smooth operation and high utilization, and thus the bottleneck drum to the maximum. In this way, feedback is created between the bottleneck and the point of entry into the system, which is called oil in DBR terminology. The rhythm of the work indicates a narrow space and the rope "pulls" parts from previous production workplaces. This configuration is typical of homogeneous manufacturing processes.

JIT (Just-in-time)

The basic idea of the JIT method was born in the fifties of the last century in the Japanese company Toyota. The reason for its creation was mainly the lack of storage space for material and final products. Its author is considered to be Taiichi Ohno, who was a Toyota production engineer. Until the early 1970s, this philosophy was used only within the company and its suppliers and was named Toyota Production System (TPS). It later spread under the name JIT to the USA and Western Europe and then to other parts of the world [6].

The company's JIT philosophy can best be used in companies with mass production, with not very variable production, and with simple production processes. On the other hand, JIT is unsuitable for piece production.

KANBAN

KANBAN is a "workshop management system" based on the JIT philosophy and also originated in Japan, at Toyota. KANBAN is a Japanese name for a card or ticket. These cards usually contain information about the place of consumption where they need the part, the place of production from which it is to be transported, and the quantity at which the part is to be delivered. The cards serve as orders within the company and, through the information transmitted, connect two workplaces (such as a paint shop and assembly) in the opposite direction than the material. The consumption point sends this order to the production point, from where the required parts are then sent back together with the card-pull system, and the material is pulled towards the customer [7].

Instead of a card or ticket, visual, voice, or electronic eKanban signals are used to indicate that the minimum amount has been reached. The KANBAN system works on the assumption that the consumer does not request components in larger quantities or sooner and the manufacturer does not produce more than necessary. At the same time, the manufacturer must pay attention to the quality of the sent components [8].

CONWIP

The CONWIP system is a newer version of the KANBAN system enriched with pressure principles. While KANBAN controls the level of work in progress with cards, and signals between individual workplaces, the goal of the CONWIP system (CONstant Work In Process) is to ensure a constant overall stock level throughout the production process thanks to global cards. The KANBAN system works on the principle of traction between each workplace. With CONWIP, the material only enters production if the card or signal allows it. This initial pull-in is followed by free production according to capacities - push system. For this reason, it is "applicable to a wider range of production systems". One card accompanies the material through all production steps. When the final product leaves the system, the cards return to the beginning of the process. In the case of another order, the card pulls the material into production again [9].

3.3. Trends in production concepts

For the company to be able to respond quickly to customer requirements, it is necessary to speed up all processes of the production company. Concepts that are the result of observing the behavior of animals in nature and concepts using new advanced technologies come to the fore.

Bionic production systems

The word bionics is composed of the names of two scientific disciplines, namely biology and electronics. Bionics is focused on the application of knowledge from the study of living organisms and their structures in the development of new technologies.

The bionic production system is also based on bionic theory. The structures and behaviors that are observed in nature, from the cellular to the animal, to the levels of the communities in which the creatures live together, can be applied to the enterprise. Here we can take evolutionary algorithms, genetic algorithms, and the way of diluting an ant colony.

Examples of the use of evolutionary algorithms for optimization can be the layout of university rooms and teaching or the division of production tasks into machine tools. The main task of optimization is to reduce the number of collisions.

As an example, the use of genetic algorithms for searches in certain state spaces can be cited, where a systematic examination of a task would take almost indefinitely [10].

Ant algorithms are inspired by the process that ants use to search for food (finding the shortest path between a food source and an anthill). At the beginning of the algorithm, the various parameters with which the algorithm works (described in the following subsections) are initialized, pheromone traces. The algorithm then works until the termination condition is met - either it can be a given final number of iterations or the achievement of an optimal solution or a solution that applies to the difficulty of the task.

As an example of bio-inspiration in production, there is one German company that specializes in the production of robotic systems. She introduced a series of flying animal robots including a penguin, a butterfly, and a jellyfish. These robots can handle data from the device or other logistics tasks. Thus, the use of this type of robot also helps to improve the production environment.

Holonic system

The Holonic production system is based on the concept of Holonic systems. Holon in Holonic production systems is designed to help the worker control the entire system by autonomously setting the appropriate production parameters, looking for their solution strategies, and creating their structure.

Holonic systems are based on the dynamic cooperation of rapidly adapting devices that can solve complex problems together without being uneconomical and inefficient due to complexity. It combines the rapid adaptability of fully autonomous, loosely interconnected systems with the stability and efficiency of classical hierarchical systems. Intelligent Holonic systems are not simple automated physical structures, but rather self-organizing entities that have their autonomous efforts and that are a mixture of the physical and virtual worlds [11].

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One example of the use of holonic systems is road maps for navigation problems. Agents in the system use these maps (basic models) in combination with a strategy to navigate from the current location to the destination location.

Agent systems and multi-agent production systems (LAG)

Technology can be classified as single-agent or multi-agent systems. In single-agent systems, the agent performs the task on behalf of a user or a specific process, and in performing the task, the agent can communicate with the user and resources of the local or remote system. Mandatory attributes of single-agent systems are autonomy, decision making, continuity of time, and goal orientation; in addition, they may have an intelligence attribute.

Single-agent systems applications include personal assistants, meeting scheduling, information retrieval, and filtering, mail management, message filtering agent, search agents, and more. Here is an agent computer program that assists a user who is dealing with a particular computer application. They may provide some of the value-added services that may be part of a package of information services when they perform different types of tasks in communicating with their user or resources [12].

A multi-agent system consists of a network of computing agents that interact and usually communicate with each other. Agents can only have a partial (and in a sense distorted) model of their environment: they can have a limited set of resources to acquire and integrate new knowledge into their models and to move the state of the system to their own goals.

Static-based LAGs are used in a variety of applications, such as distributed vehicle monitoring, computer-integrated manufacturing, natural language analysis, telecommunications, and network management, aircraft maintenance, military logistics planning, real-world simulation, and satellite propagation.

3.4. Technology development trends

The term "Industry 4.0" comes from a project of the German government in the field of high-tech strategy. The date was first proposed in 2011 at the Hanover trade fair, followed by plans. Key elements include interoperability of different systems, decentralization, real-time analysis, and flexible services. The integration of their facilities, warehousing system, and production services in the form of cyber-physical systems [13] will make it possible to improve existing industrial complexes.

CPS offers new forms of solutions with a reduced role of mechanics or hardware and a growing role of software applications [14]. It is a continuous development of IT-based tools and applications combined with extremely advanced IT systems that have huge storage capacities and high transfer rates. CPS can be considered as a system that has a direct connection (intelligent combination) between the "real" and the "virtual" world.

The technologies of the fourth industrial revolution are blurring the boundaries between the physical, digital, and biological spheres of international production systems. The current pace of technological progress is causing profound changes in the way people live and work. It affects all disciplines, from planning through economies to industries, manufacturing to products and services [15].

Here are some of the most important features of Industry 4.0 [16]:

- Availability and use of the Internet and the Internet of Things.
- Integration of technical processes and business processes in companies.
- Digital mapping and real-world virtualization.
- "Smart" factory, including "smart" means of industrial production and "smart" products.
- Industry 4.0 could lead to reduced production, logistics, and quality management.

The Internet of Things is the key to turning any system into a smart one. So that the Internet of Things benefits the manufacturing industry by connecting objects via a network and remotely managing existing network infrastructure, thus opening up opportunities to integrate the manufacturing world into computer systems, thus improving production efficiency, product accuracy, and economic growth and minimal intervention man. New operating systems are used to meet the requirements of modern systems. There are many platforms for the Internet of Things that have been developed.

The Internet of Things is a system of interconnected sensors, and when data needs to be processed, several layers need to be added. The Internet of Things can also use artificial intelligence and machine learning to facilitate and streamline data collection processes [17].

Big data

The sensors are installed in the facilities and on the premises and then the data they collect is analyzed. This data is Big Data, it can be used to monitor the condition of the equipment, model production processes, and detect and prevent failures.

Thus, in general, the term Big Data describes data that can be high in volume or diversity, or that can be collected at high speed with potential high or low truth so that ever-specific analytical technologies are needed to turn it into valuable information.

Big Data technology can be used for various purposes such as:

- Accident prediction and production optimization.
- Freight planning and route optimization.
- Personal offers and product layout optimization.
- Increase profits and attract customers.
- Reduce product costs and optimize production

Cloud Computing

Cloud Computing is one of the most modern computing technologies that can help solve the problems of dynamic data growth and growing demand for computing units that will be able to process and analyze data promptly. Cloud computing provides plenty of storage space, computing networks, hardware, and software resources as a service, without the need for extensive on-demand configuration as needed. With the information in the Cloud and a connection to the Internet of Things, production can be efficient by combining the work of humans and collaborative robots. Production information will be constantly collected on the Cloud, where productivity analysis will be created in real-time. Cloud Computing can also be used in all other processes in the company, for example in the planning process or the pros of maintenance, and storage.

Artificial intelligence

Companies collect vast amounts of unstructured data from a variety of sources, such as machine sensors, production lines, production execution systems, enterprise resource planning systems, off-site systems (customer feedback, supply chain), and other miscellaneous purposes. The analysis of this data creates a competitive advantage and creates new products and services.

When we talk about artificial intelligence, it can be divided into two types of artificial intelligence. Software: virtual assistants, image analysis software, search engines, speech and face recognition systems. Built-in material facilities: robots, self-propelled cars, drones, the internet of things

Software that has artificial intelligence can be used to look for irregularities and mistakes that go through the balance. Such software needs several product images to detect deficiencies in a very short time frame.

In smart factories inspired by the modern manufacturing industry, the use of AI facilitates fast decision-making based on real-time and historical data with minimal human involvement.

Thus, with the help of artificial intelligence, it is possible to create a remote mechanical product design system that uses artificial intelligence for image processing and pattern recognition and uses wireless client/server communication [18].

3.5. Summary of theoretical background

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It follows from the above that it is very important for the company to choose an appropriate philosophy of business management, to use adequate methods of production process management with the implementation of such technologies that will bring production efficiency ensuring the company's competitiveness in the long run. Fulfilling the expectations of all parties involved (customers, employees, shareholders, suppliers, investors ...) is a matter of course, but the actual implementation of such a step is challenging.

The publications, which deal with individual methods and technologies of production process management, describe the individual approaches in a very similar way, but they no longer deal with how to compile in detail the composition of methods and technologies that would bring the expected result.

The performance of the production process of the production system can be evaluated using known indicators. However, the authors of the publications do not state how and based on which companies should put together suitable methods and technologies for production management corresponding to the needs of individual areas of the production system, which will ensure an increase in the performance parameters of the production system.

The company needs to follow the development trends of new technologies and the published approaches of their creators. There is studio studies presentods and technologies on initialization implementations, which then serve as demonstration solutions. In the pre-implementation phases, each supplier presents the expected costs, the schedule of the solution, and the expected benefits of the solution through basic recalculations of the return on investment. Current implementation tools already make it possible to implement the model and simulation results as the production process is improved using selected technologies. However, the company will find out the real results and find out only after the implementation and start-up of the real production mode of production [19].

Key performance indicators are important to verify that the chosen method and technology have achieved the desired result [20], [21]. At present, modeling systems make it possible to verify to some extent the impact and behavior of the production system when changing the management method. General procedures for creating simulation models can be found in several publications, authors [22], [23].

However, in the available resources, it is not possible to have a comprehensive system for analyzing the impact of a combination of specific methods and technologies on the efficiency of the production process. [24], [25], [26]. The result of the analysis would help guide management for a specific selection of progressive methods and technologies to improve the management of current production processes. In their proposal, the authors built this selection, which uses the knowledge of companies already implemented in practice.

The industry is experiencing global change with the emerging Industry 4.0. This new key concept is fundamentally changing the shape of not only business processes but also the entire company [27-29].

4. Analysis of curret state

The questionnaire survey was aimed at finding out the current state of use of production management methods and technologies used by companies. A sample of 100 companies from the Slovak Republic took part in the survey. Brief characteristics of the representative sample of participating companies on the questionnaire. The largest share of respondents was from the automotive industry (67%). Of the number of respondents surveyed, 57% of respondents have a serial type of production. The analyzed sample represents a 37% share of respondents with a continuous production process. An important part of the survey was to determine the use of production control methods in the sample of companies, Figure 1.a.

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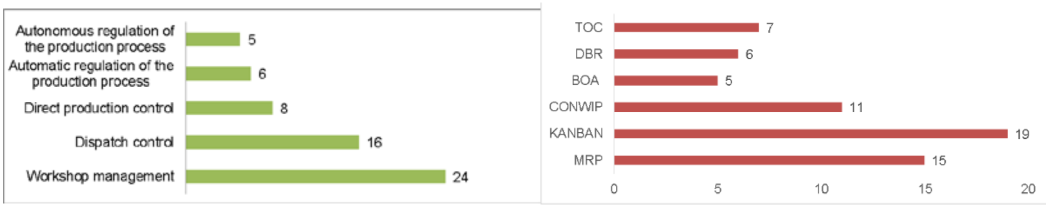
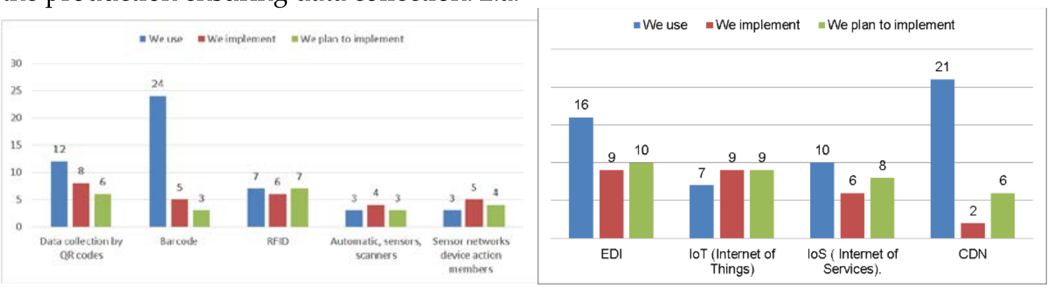


(**a**) (**b**)

Figure 1. (**a**) Use production control methods; (b) Workshop Production Management System, Survey 2021.

The survey showed that the most used is the KANBAN and MRP control system, Figure 1. b. Furthermore, the survey points to the representation of technologies in the production ensuring data collection. 2.a.



(**a**) (**b**)

Figure 2. (a) Production technologies (data collection); (b) Data Exchange and Retention Technologies, Survey 2021.

Another monitored group is technologies providing data exchange, Figure 2.a. and their preservation, Figure 2.b. The last group is the technologies used for data analysis (Figure. 3).

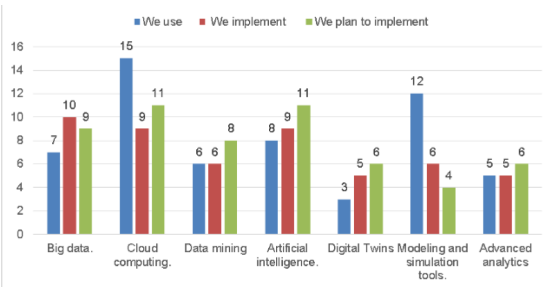


Figure 3. Data analysis technology, survey 2021.

Based on a survey of manufacturing companies, it can be stated that companies use different management systems, and apply different methods and technologies. It is not possible to get an answer from the survey to what extent the choice of technologies and methods influences the efficiency of management processes.

The authors hypothesize that the level of use of individual technologies and their correct deployment affects the effectiveness of process management. Therefore, the authors tried to design a system that would reveal these connections and, based on the acquired knowledge, help in their selection.

The decision-making would be based on the acquired knowledge and experience of the methods and tools applied so far for streamlining production management, which helps companies to manage production processes more efficiently.

5. Results and discussion

The proposed system consists of five basic blocks, Figure 4: data collection, benchmarking of industrial process performance, block examination of differences, block of data

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mining to gain knowledge about the impact of used methods and technology on process performance and from the presentation of results, which helps to make recommendations for selecting progressive method and technology according to required goals.

The data collection block is filled with input data about the manufacturing company using a form. Subsequently, the company is classified and classified according to related production characteristics. The benchmarking block will provide a comparison of companies in a given class and look for the best-achieved results in the performance and efficiency of production and overall business within individual segments. The differences examination block will allow tracking if the implemented methods and technologies do not provide the expected results. The data preparation block processes detailed information on the achieved results of individuals who used progressive methods and production management technologies necessary for the analysis. Block data analysis, using data mining techniques, seek connections between the application of progressive methods and technologies for production management and their contribution to the change of performance parameters and production efficiency. The last block of the system, the presentation of the results of the best solutions for the company, helps through the criteria to select the procedure for the application of appropriate progressive methods and technologies. The recommendations are based on the applied "best of practiced" solutions already from the implementations stored in the system.

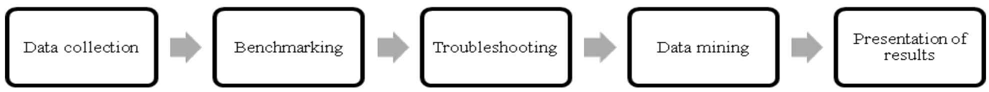

Figure 4. System blocks for the selection of progressive methods and technologies.

5.1 Data collection about a manufacturing company

The first block of the system of selection of progressive methods and technologies to streamline the management of the production process is data collection (Figure 5). This block is used to collect the necessary data for further processing in the so-called (Figure 6.) Classification is a mechanism that assigns a number to the relevant segment according to prproductharacteristics.

The input data cover the following areas:

- Characteristics of the company: the size of the company, subject, and nature of production, used production technologies, resources, level of automation, and share of evaluated production from the entire product range.
- Production planning and control: used planning methods and methods of production management, monitored indicators of achieved performance and efficiency of the production process.
- Technologies for production management: information systems, data collection and storage systems, data analysis technologies, decision support technologies.
- Indicators of production efficiency, quality, and availability of resources.

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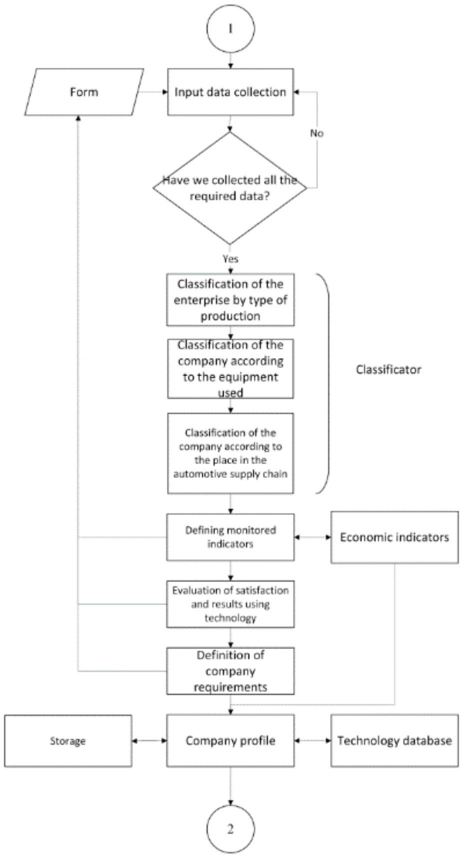

Figure 5. Data collection, procedure steps.

Classification of information of production companies based on product characteristics into classes Figure 6 will allow the inclusion of companies with the same characteristics in the group:

- Type of production according to the degree of repeatability (piece production, series production, mass production, or personalized production).
- Position in the automotive supply chain. Businesses can be divided into three groups:
- Builder - names a direct supplier with several assembly groups and systems.
    - Direct suppliers - are suppliers of subassemblies and individual assembly parts.
    - Indirect suppliers - include suppliers of raw materials and individual components, such as fasteners.
- Type of equipment used - a system targeted at the automotive industry in which there are different companies in terms of the equipment used, it is necessary to prevent the system from comparing companies with, for example, hand tools and companies that use automated lines.

The next step is to obtain information about the achieved production performance, which indicates the level of impact of the methods and technologies used. The basic performance indicators of production processes include:

- Performance of the specified workplace, operation, and process.
- Productivity of the specified workplace, operation, and process.
- Product quality because of the error rate of processes.
- Continuous production time.
- Length of downtime and their frequency.
- Overall efficiency of OEE equipment.

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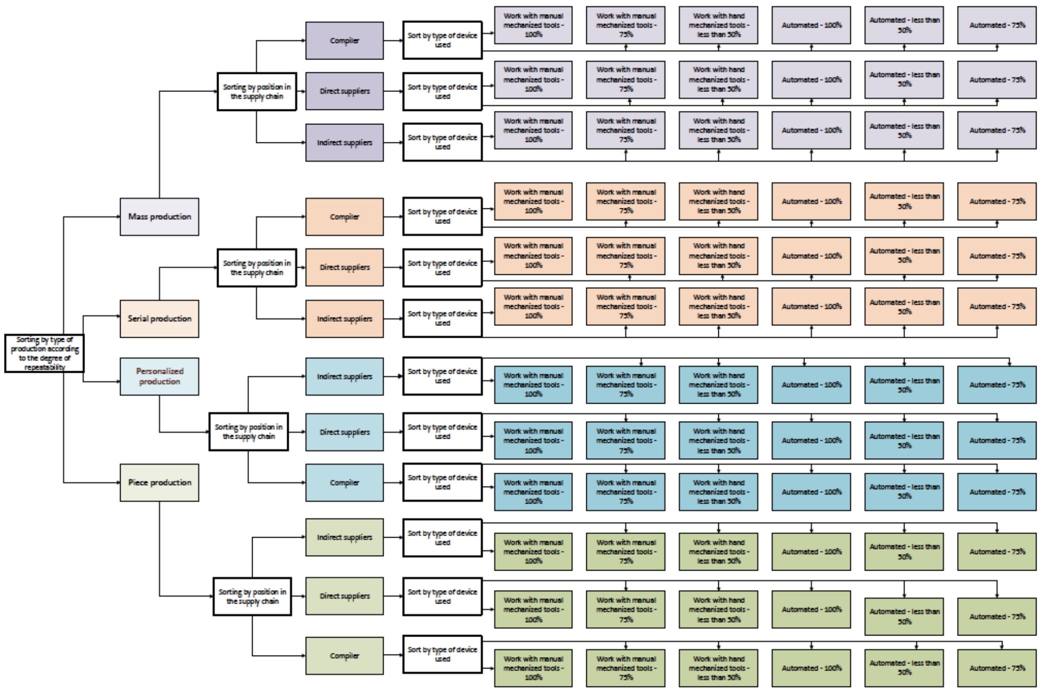

Figure 6. Design of classification for the management of related segments.

An important piece of information when choosing a method and technology is the level of satisfaction of the company with the change in efficiency and effectiveness of production processes Table 1 and Table 2.

Table 1. Form for determining satisfaction with the implemented method of production management.

When was the last time you changed implemented methods?					
One year ago		More than 3 years	More than 5 years	Never.	
How satisfied are you with the implemented methods?					
Very satisfied	Rather satisfied	Neutral	Rather dissatisfied	Very dissatisfied	
How would you rate the following indicators?					
	Very satisfied	Rather satisfied	Neutral	Rather dissatisfied	Very dissatisfied
Error rate					
Troubleshooting					
The difficulty of the procedure					

Table. 2 Form for determining the satisfaction of the company with the used progressive technology.

How long have you been using technology?				
Less than 6 months	6 months to 1 year	1 year to 3 years	3 years to 5 years	More than 5 years
How often have you changed the use of technology in your business?				
Every year	Každých 3 roky	Každých 5 rokov	Nie menil som ešte.	
How satisfied are you with the technologies used?				
Very satisfied	Rather satisfied	Neutral	Rather dissatisfied	Very dissatisfied
How would you rate the following indicators?				

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	Very satisfied	Rather satisfied	Neutral	Rather dissatisfied	Very dissatisfied
The price					
Ease of use					
Error rate					
Response speed					
Difficulty					

Important information also includes data on the financial health of the company, which are publicly available. Financial health should be understood as the finding of the achieved economic indicators before and after the introduction of new technologies, such as profit, sales, assets, and total revenues. This type of information needs to be considered sensibly, as investments in new technologies result in different payback periods, and this partly affects economic indicators.

5.2 Business management performance benchmarking

The second block of the system of selection of progressive methods and technologies to streamline the management of the production process is benchmarking aimed at comparing the performance of participating companies (Figure 7). The purpose of benchmarking is to find out from the collected data the representatives with the best-achieved results of efficiency and effectiveness of the production process in each segment of related companies. It is necessary for the Benchmarking block:

- Define the items that need to be compared in the data.
- Define between which items the comparison should be performed.
- Ensure the download and collection of information from the data collection block.
- Setting criteria for the comparison process.
- Defining the output form of the obtained results for the next processing.

Visibility of successful companies is a source of knowledge in finding the best solutions to improve the management process. If the result of the benchmarking has provided important information to the system for the monitored company, it is possible to stop the process of further processing the selection of the appropriate method and technology and use it. After the implementation of the technology, it is possible to re-check the repeated benchmarking and then continue to select and recommend progressive methods and technologies (Figure 6).

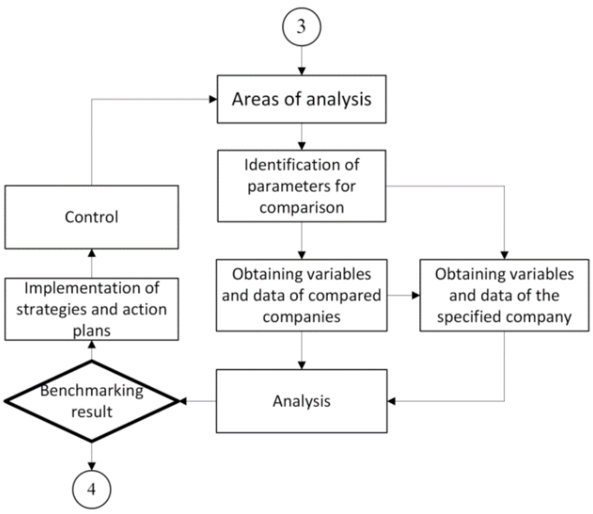

Figure 7. Benchmarking processes.

Benchmarking inputs are:

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- Methods and technologies used for production management.
- Evaluation of companies' satisfaction with the use of methods and technologies.
- Achieved results of selected indicators of production operation.
- From the implementation of Benchmarking it is possible to know:
- Ranking of the success of companies with the best results in a given segment.
- The order of success and the occurrence of the methods and technologies used in the companies with the best results.
- Order of change success for selected production indicators.

5.3. Examining the differences

The block allows companies if its methods and technologies are the same as the best companies but do not achieve comparable results in the performance of the system allows the system to examine the differences regarding proper setup and use (Figure 8). It is important to verify whose management of the production process is affected by any of the elements and the internal environment. In the next step, the proposed system helps to analyze errors in setting up and using already implemented methods and technologies.

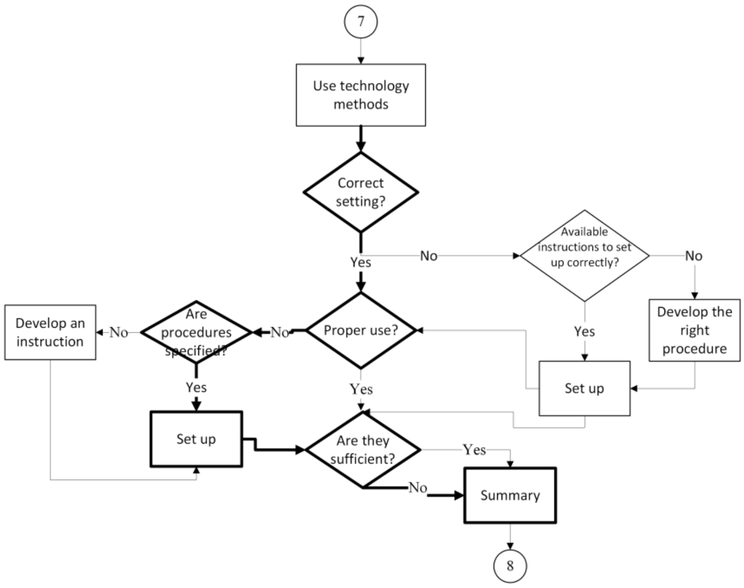

Figure 8. Steps of analysis to examine the correct setting and use of technology.

This step eliminates the possibility that the method or technology is selected for the business correctly, but an error occurred, for example, in the implementation, training, or other internal environmental impacts.

5.4 Data mining

Data mining block (Figure 9) using data mining techniques, seeks connections between the application of progressive methods and technologies for production management and their role in changing the parameters of production efficiency and effectiveness.

It provides an answer to the question to what extent the implementation of the chosen management method and technology contributes to the improvement of the production indicators of the production company in the selected segment, group. A data mining tool is used to evaluate, where it is possible to create a model and perform tests on a sample of data. By applying data mining methods, it is possible to obtain results based on which it is possible to confirm that technologies and methods have a positive or negative effect on streamlining production management, ie that the investment may be risky.

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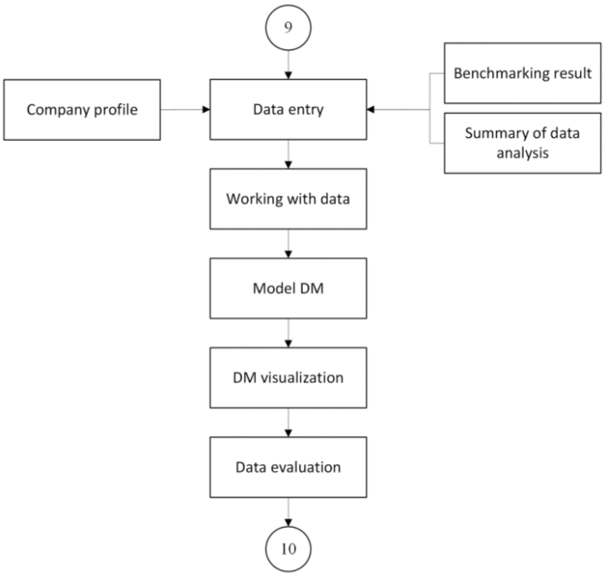

Figure 1. Data mining, step-by-step procedure.

Several analytical tools available freely but also licensed can be used for data mining. Known systems include RapidMiner, Oracle Data Miner, Hadoop, Orange, and others. The input data is taken from the passing blocks of the system. The data need to be processed and prepared for analysis. FIG. 10 shows a data model in an Orange environment (Open source machine learning and data visualization)

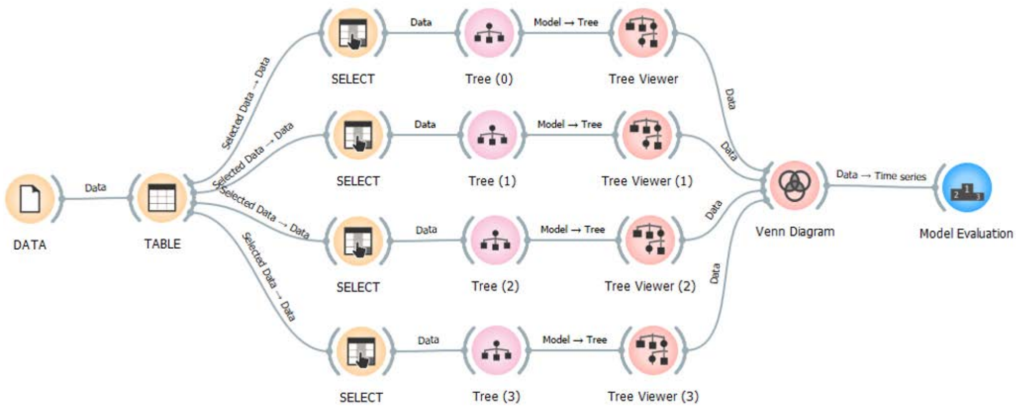

Figure 10. Data model for analysis with Orange.

The result of the analysis is represented by the visualization of the model tree in Figure 11. In the Orange environment.

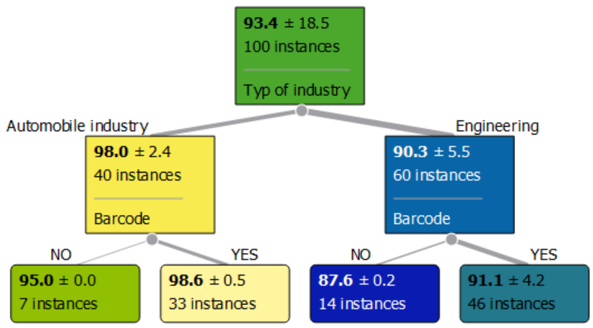

Figure 11. Decison tree classification with Orange.

From the data of the verified company XYZ Table 3 and from the data obtained in the framework of benchmarking from companies from the related segment, it is possible

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to find out which applied progressive methods and technologies for production management have the potential to increase production efficiency and effectiveness.

By analyzing the data provided by the companies using the decision tree classification, it is possible to find out for which combination of methods and technologies the best results are achieved in the production management process. The evaluation of the level of the achieved results is through the obtained data (Table 6).

Finding the best solutions can be seen using the Venn diagram, (Figure 12). The diagram for the case of the XYZ company shows that the most frequently used methods and technologies in the given segment with satisfactory results are listed in (Table 4).

These production management methods and technologies are also available to companies under the code names XYZ1, XYZ2.

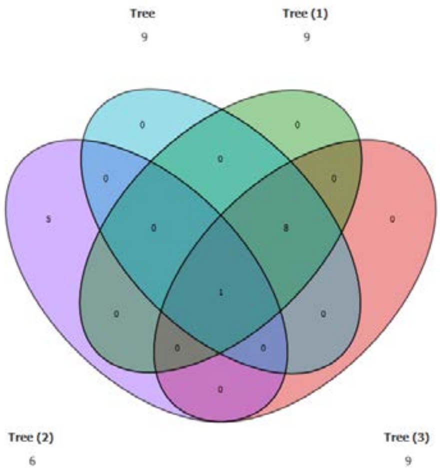

Figure 12. Venn diagrams**.**

5.5 Presentation of results for the selection of progressive methods and technologies

The results obtained from benchmarking and data mining need to be systematized, analyzed, and adjusted to a usable form to provide a comprehensive view of the direction that the assessed company XYZ wants to take in the future. The output of the results presentation block is the resulting combination of methods and technologies, which is recommended based on "best of practices" experience from proven solutions for streamlining production management processes. According to the characteristics, it can be seen that companies in the same group operating in the automotive industry they are direct suppliers. In terms of the method and degree of repeatability of production, companies have personalized production. The difference can be seen in the automation of the device. Therefore, they are in different classes. So they also use different materials for production. Enterprises have specialized machine operators, which are conditioned by the type of product according to different levels of repeatability. It is possible to see the difference in logistics mechanization (Table 3).

Table 3. Characteristics of companies.

Company Name:	**XYZ**	**XYZ1**	**XYZ2**
Industry type:	Automobile ıdustry	Automobile industry	Automobile ıdustry
Position in the automotive supply chain:	Direct supplier	Direct supplier	Direct supplier
Production type according to different levels of repeatability:	Personalized production	Personalized productior	Personalized production
Type of device used:	Automated - 50%	Automated - 50%	Automated - 75%
The class	426	426	425

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The production process in terms of method and degree of repeatability of production:	Discontinued production	Non-cyclical	Discontinued production
Material of the main product	Metal, Aluminum	Metal	Aluminum
Production service (workers)	Specialized	Specialized	Specialized
Logistics	Mechanized -75%	Mechanized - less than 50%	Mechanized -100%

Another group for assessment is the implemented production planning and control system. Analyzed companies use very similar systems for production planning and control. The difference in companies can be seen in the type of maintenance applied. Important differences are in the methods of production management; the selected company has an urgent management (Table 4). The disadvantage of this method is the large time variability of work in the operation and the influence of the size of stocks at controlled workplaces.

Table 4. Monitored parameters of production, maintenance, inventory planning, and management.

Company Name:	XYZ	XYZ1	XYZ2
Type of maintenance	Maintenance after failure	Scheduled Preventive Maintenance	Scheduled Preventive Maintenance
Planning of production	According to orders	According to orders	According to orders
Material flow routing:	Routing according to orders	Routing according to orders	Routing according to orders
Inventory management	At the point of disconnection of customer orders (independent demand)	At the point of disconnection of customer orders (independent demand)	Before the customer order disconnection point (dependent requirement)
Production management methods	Urgent management	Direct production control	Direct production control
Workshop production management system:	MRP	MRP	KANBAN
Methods of work process management in terms of logistics	ERP	ERP	ERP

In the group for compared technologies are assessed technologies focused on data collection and data exchange, for data storage and analysis, which are often used by the production management systems (Table 5).

Table 5. Applied technologies for working with data.

Company Name	XYZ	XYZ1	XYZ2
Data collection	Barcode	QR code	RFID, Sensors
Data exchange	EDI	IOT	IOT
Data storage and processing	Database	Database	Cloud computing

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Data analysis technologies and tools Technologies supporting production management systems	Modeling and simulation tools Mechatronic systems	Advanced analytics Mechatronic systems	Modeling and simulation tools Mechatronic systems

Another part of the analysis concerns data storage and processing. By leveraging Cloud Computing, business management processes make data processing easier, faster, and more efficient. IoT allows the interconnection of individual operations, which prevents communication errors that can lead to the loss of important data. Cloud technologies enable data storage, analysis, and subsequent evaluation.

The last group for comparison is economic and financial indicators. The basic indicators of the production process in operation include continuous production time, length and number of individual downtimes, production performance, the overall efficiency of the equipment, and the achieved level of productivity (Table 6).

Table. 6 Monitored production and economic indicators of operation.

Company Name:	**XYZ**	**XYZ1**	**XYZ2**
Production lead time:	8 weeks	6 weeks	6 weeks
Highest production downtime/share:	Machine failure rate / 25%	Technological downtime / 22%	Delivery of materials / 15%
Production capacity:	80 %	75 %	80 %
Achieved quality:	85 %	85 %	94 %
OEE:	75 %	68 %	78 %
Production productivity:	81 %	87 %	98 %

6. Conclusions

The system of selecting progressive methods and technologies to improve the management of production processes provides the company with three scenarios, which differ in the implementation of selected technologies that will allow XYZ to approach companies in a given segment. The scenarios relate to the knowledge gained from the results of process management in production facilities with the support of selected methods and technologies. Individual scenario variants (Table 7) present the options that XYZ could choose. If the company decides not to interfere in the automation of the device, Variant No. 1 is recommended. If the company decides to increase the level of automation, Variant No. 2 and Variant No. 3 correspond to this. Cells in bold are potential proposals to change the method and technology that support production management.

Table 7. Presentation of results.

Parameters:	Variant č.1	Variant č.2	Variant č.3
Automation level:	Automated - less than 50%	**Automated - 75%**	**Automated - 100%**
Logistics level:	Mechanized - 100%	Mechanized - 100%	Mechanized - 100%

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Implemented type of maintenance:	**Scheduled Preventive Maintenance**	**Scheduled Preventive Maintenance**	**Scheduled Preventive Maintenance**
Production planning method:	According to orders	According to orders	According to orders
Material flow routing:		Routing according to orders	
Production control method:	**Direct production control**	Workshop management	Direct production control
Workshop production management system:	MRP	MRP	**KANBAN**
Data collection:	**RFID**	**RFID**	**Sensors**
Data exchange:	**CDN**	**EDI**	**IoT**
Data storage and processing:	Database	**Cloud Computing**	**Cloud Computing**
Data analysis technologist and tools:		**Modeling and Simulation Tools and Advanced Analytics**	
Technologies supporting production management systems:	**SCADA a Plug and produce**	**SCADA**	**SCADA**

The submitted contribution deals with the design of a system that will support the selection of progressive methods and technologies to improve the management of production processes in the automotive industry with the aim of ensuring the sustainability of production efficiency.

The presented system is based on the use of knowledge of existing solutions of manufacturers of automotive components, where companies solve similar problems in production management.

The proposed system for supporting the selection of the production management method and technology is designed from blocks of data collection, benchmarking of the performance of production processes of industrial enterprises, further from data mining technology to obtain knowledge about the effect on efficiency from already implemented technologies. The last blocks help to examine the differences in the implementation of identical methods and technologies and allow the manager to present the obtained results in the form of recommendations for the selection of a suitable progressive method and technology in a given segment or group. During the research, the authors found that as technology continues to evolve, new technologies will need to be described and classified in more detail. It should be emphasized that only companies that expressed an interest in sharing their experience and are mainly motivated to improve their management and production processes participated in the research.

The description of the proposed system and its use is also supported by the fact that new technologies are being developed around the world that enable the collection and evaluation of data in real time. These new technologies, together with new, more complex customer requirements, lead to a change in the paradigm of product production and to the development of new methods of deploying progressive technologies to make production systems more efficient.

In practice, the solution is naturally used on a case-by-case basis from the point of view of application technology for the selected nature of production, type of production, ban on the use of production resources, nature of production resources and business model of the production company, as well as available IT infrastructure. They often look to search analytics to solve the problem. The basis of the evaluation of the choice is a documented calculation of the return on investment invested in the procurement of advanced technologies plus the recommendations of sellers and their satisfied customers.

The paper describes a system that respects the so-called The golden rule that says you should follow the best of the best.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, O.K. and V.B.; methodology, L.C.; software, V.B.; validation, P.B.., V.B. and O.K.; formal O.K..; resources, P.B.; data curation, M.R.; writing—original draft preparation, O.K.; writing—review and editing, V.B.; visualization, V.B.; supervision, M.R.; project administration, P.B.; funding acquisition, V.B.

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