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Validation of the Heuristic Model for SMART Management in a Medium-Sized Industrial Enterprise

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Abstract: This article presents the results of the approbation of a Heuristic model for SMART management in a medium-sized industrial enterprise in a specific economic entity. The main practical steps and the effects achieved as result of the introduction of the model in the selected industrial enterprise are summarized. The results achieved at different stages and the analytical assessments, the improvements, the restructuring and other strategic and operational activities leading to effective changes in the operation of the industrial unit are presented. Conclusions and inferences have been made, the most important of which is that the Heuristic Model for SMART management in the medium-sized industrial enterprise is also applicable in small industrial enterprises having a complex and multi-layered structural architecture. In order to comply with the regulation of the European Union for the protection of personal data, the name of the company is not indicated in this article, and the provided data is publicly available.

Keywords: Approbation, Heuristic model, SMART management, Industrial enterprise

Introduction

Under the conditions of Industry 4.0, the options for integrating technological network connectivity with the possibilities of the heuristic tool-kit, as well as with the possibility of upgrading the heuristic systems with the experience acquired on the basis of artificial intelligence and expert systems, give reasons to look for a definition of the concept of «a heuristic model for SMART management in the medium-sized industrial enterprise ». The author defines this model as an arbitrary algorithmic process based on a SMART tool-kit and heuristics that provides optimality or compromise improvement of management in all or in specific functional planes of the organization. This model integrates, on the one hand, the latest technological innovations such as cloud computing, mobile connectivity, large databases, artificial intelligence, additive manufacturing and the Internet of Things, and on the other hand, the business practices introduced through machine self-learning and the expert systems bringing human expertise to the algorithm of codes and data. The heuristic model for SMART management in the medium-sized industrial enterprise is a final, simplified, adequate image of a real intelligent management process and should be described in detail and decomposed into its constituent fundamental elements by defining its input-output information flows.

In the course of the approbation of the Heuristic Model for SMART management in the medium-sized industrial enterprise the specific industrial enterprise will organize its activity on the basis of the integrated and model-based analysis, assessment, forecasting, planning, organization, control. The aim is for the subject of approbation to keep its structure and work processes flexible and adaptable to the changes in the environment. On this basis, the process of testing the Heuristic Model for SMART management in the medium-sized industrial enterprise comes down to:

- analysis and assessment of the environment of the industrial enterprise and its production processes;
- study of the "production – management" relationship within the industrial entity chosen for testing the model;
- decomposing the systems of the industrial entity into subsystems and of production into processes and operations;
- determination of the mathematical foundation of the Heuristic model for SMART management in the industrial enterprise selected for implementation of the model;
- refinement of the heuristic elements in the Heuristic Model for SMART management in the industrial enterprise selected for selected for testing the model;
- creating a software information technology foundation in the industrial entity;
- selection of a specific control parameter (corresponding to the specifics of that industrial entity) in the industrial enterprise selected for testing the model.

The specified activities lead to the specific formal implementation of the Heuristic model for SMART management in the medium-sized industrial enterprise according to the individual conditions of the environment and the specifics of the activity. For the purposes of this study, the testing of the Heuristic Model for SMART management in the medium-sized industrial enterprise took place in an industrial enterprise headquartered in the city of Targovishte – i.e. a region outside the capital of Bulgaria, located in the north-eastern part of the country. The business unit in which the Heuristic model for SMART management is implemented in the medium-sized industrial enterprise was registered in 2001 with a wide scope of activities in this country and abroad:

- production, processing and sale of industrial, household and agricultural products;
- production of furniture and details from wood and timber and their marketing;
- wholesale and retail trade in goods permitted by law;
- commission and brokerage activity;
- construction and repair activities;
- electrical installation and repair work;
- hotel and restaurant management;
- entertainment, fun and amusement games;
- transport and car repair activities;
- repair of industrial and household appliances;
- trade in petroleum products;
- foreign trade activity;
- marketing and management after obtaining the necessary licenses for the relevant activities.

According to the registration, the main activity under the National Classifier of Economic Activities is the production of furniture. Based on the brief historical retrospection of the registration of the company, it becomes clear that it has over 20 years of experience in the creation of custom furniture and the implementation of assignments from partners and traders. Today, part of the company's production provides products for a well-known Swedish company - a leader in the online sales of furniture on the Scandinavian market. A check with the Information System for the management and monitoring of funds from the European Union in Bulgaria showed that the company is a beneficiary of four projects under Operational Programme "Innovations and Competitiveness". The funding agreed for these projects amounts to BGN 2,085,924.50, and the amounts actually received, based on verified activities and expenditure justification documents are BGN 1,379,379.10.

The economic entity chosen for the testing of the Heuristic model for SMART management in a medium-sized industrial enterprise is a small industrial enterprise with a total workforce of 35 employees. The turnover of the company varies from BGN 1,852,000 in 2019 to BGN 2,199,000 in 2020 (https://portal.registryagency.bg). The company's assets amount to nearly BGN 2,000,000.

At the same time, the company selected for testing the Heuristic Model for SMART management in a medium-sized industrial enterprise is one of the formal exceptions to the generally accepted definition of a medium-sized industrial enterprise. This exception is defined by the European Commission, which assumes that "if an enterprise has access to significant additional resources it might not be eligible for the status of a small or medium-sized enterprise" (European Union, 2020). This means that the size of the economic entity is not the only factor to consider when defining an enterprise as a small or medium-sized enterprise. Therefore, the more complex structure of the company, its access to significant resources, including through EU funds, the object of its activity, the presence of a real substantial transformation process, are essential factors in defining its type.

The reason for choosing the company in which the testing of the Heuristic Model for SMART management in a medium-sized industrial enterprise took place as the subject of the study is related to its rapid development and the potential it shows for growth and expansion of the market share in the external environment, including on the international market. The company's strategic priorities indicate that it has focused its activities on expanding its structure and markets. It is clear from the mentioned arguments that the company has the capacity to restructure into a medium-sized industrial enterprise. This is also the main reason for choosing it as the subject of the testing of the Heuristic Model for SMART management. The aim is to analyse the ability, through the introduction of the model, of the industrial enterprise to accelerate its formal growth to a medium-sized industrial enterprise, and the introduction of the Heuristic model for SMART management is accepted by the company's management as a first step in the achievement of this strategic goal. The purpose of the approbation of the Heuristic Model for SMART management in the selected industrial enterprise can be synthesized as follows:

- reduction of resource intensity;
- increasing the capacity and production workload;
- increasing adaptability;
- sustainability of processes;
- optimization of stocks and warehouse stocks;
- optimization of the need for production land;
- planning sustainability.

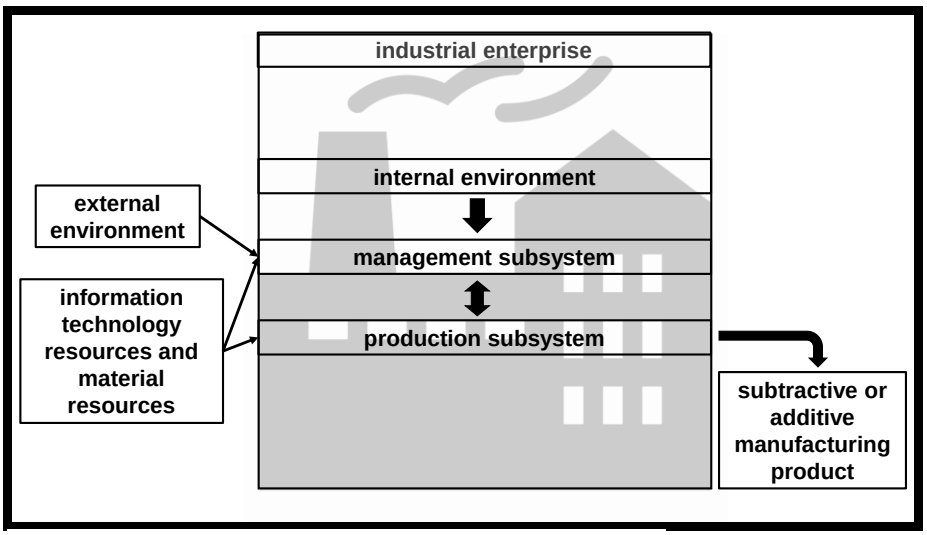

Figure 1. Structure of the industrial enterprise subject to approbation of the Heuristic Model for SMART management in the medium-sized industrial enterprise (developed by the authors)

The company chosen for testing the Heuristic model for SMART management in a medium-sized industrial enterprise is a unique production system, the constituent elements of which are production equipment and information and analytical equipment, technological processes, technical means of control and management and people involved in the service and management of the production process. The input materials (chipboard, timber, locks, hinges, fasteners and other elements) are transformed under the influence of the dispositive factors of production and the management subsystem into a final commodity product (Figure 1.). On this basis, it implements industrial production activities, which, taking into account the conditions of limited resources and organizational and structural complexity, determine its strategic priorities in time and space. (Temelkova, 2010).

Testing of the Heuristic Model for SMART Management in a Medium-Sized Industrial Enterprise

The testing of the Heuristic Model for SMART management in a medium-sized industrial enterprise in the selected company requires passing the stages described above in the article. The first stage of the testing is related to an analysis of the environment of the subject in which the model is tested.

The analysis and assessment of the environment of the industrial enterprise requires study of the environment external to the company using a set of strategic tools:

- The Political, Economic, Social, Technological Analysis indicates that the factors related to an increase in the cost of production per unit of production negatively affect the company's activity. At the same time, the factors leading to better quality parameters of production and to options for larger production volumes are evaluated positively.
- The Industry Analysis of the "Furniture Manufacturing" sector indicates that its attractiveness is moderate, as it is influenced by the moderate rates of demand and profitability in the sector. At the same time, the high supply in the industry and the low degree of regulation of supply through barriers to entry into the industry lead to the need to search for sustainable tools to minimize the cost of production of a product unit.
- The Competitive Analysis highlights three groups of competitors of the investigated enterprise: companies similar to the investigated enterprise; companies specializing in a narrow product niche; regionally operating companies.
- The study of the driving forces of competition of the analysed economic entity, according to Michael Porter's model, reveals that the forces of competition act intensively, that the access of new players to the industry is facilitated, and the power of suppliers and consumers is moderate. Thus the possibility of the company's products to be replaced by substitute goods is tangible. This necessitates a search for options to increase the added value of production.
- Competitor Profiling gives a clear and accurate view of the strengths and weaknesses of the investigated company which enables to estimate its potential and vulnerability. It is evident from the assessment of the company's competitive advantages that it also has the potential to gain better market positions and capacity. (Figure 1).

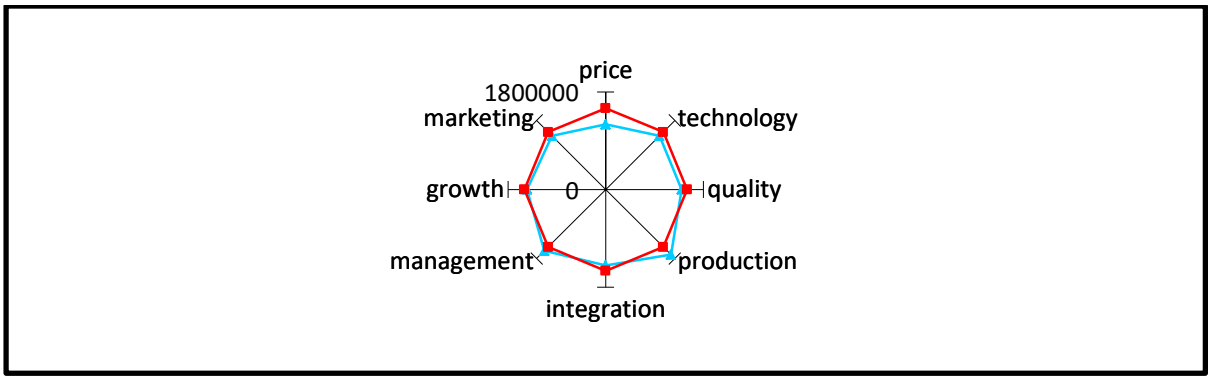

Figure 2. Competitive profile of the investigated company, object of approbation the Heuristic Model for SMART management in the medium-sized industrial enterprise is introducted (developed by the authors)

- Pressure Analysis defines several main groups with specific interests: owners, managers, workers and employees who are part of the internal environment of the industrial enterprise, and suppliers, consumers, society, who are part of the external environment of the company. There is a match between the interests of owners and managers and an indirect match between their interests and the interests of the company's employees and suppliers. Optimizing costs and profits would lead to the satisfaction of the interests of all studied groups of the community.

Table 1. Key Success Factors Analysis of the investigated company where the Heuristic Model for SMART management in the medium-sized industrial enterprise is introducted (developed by the authors)

Factor	Priority Requirements to Achieve Success in the Sector
Proposal of a Suitable Product/Furniture	modern design innovative form long product line colour variety warranty
Offering at an Affordable Price	delivery and assembly high quality custom design specialized stores
Offering at a Suitable Place	website opportunity to choose proper customer service consulting clients

The internal environment of the company, subject of the testing of the Heuristic model for SMART management in a medium-sized industrial enterprise, is investigated using a set of analytical tools:

- Key Success Factors Analysis is based on a company's fulfilment of the requirements of three factors leading to success in that economic sector. The success in the industry and the growth of the company to a medium-sized enterprise is a realistic strategic move based on the optimization of the production by reducing the resource intensity and by increasing the capacity and the market share (Table 1).
- The Strategic Product Analysis indicates that custom production increases during the summer months, and it is the weakest at the beginning of the calendar year. Regarding standardized products, it is observed that they are in the "growth" stage of the life cycle, which substantiates the thesis that the company has the potential to expand its market share.
- Analysis by the Boston Consulting Group provides information on the strategic positions of the manufactured products on the market and in the company itself: the "cash cow" products are the kitchen units, the wardrobes and the bedrooms; the "star" product is the shelves; "dilemma" products are the chests of drawers.
- The activities in the industrial enterprise subject of analytical analysis which add more value and require significant costs were identified using the Value - Chain Analysis technique: the production operations for converting raw materials and materials into finished products through processing, cutting, assembly, testing, and the internal logistics encompassing the receiving, warehousing, storage and distribution of material resources.
- The studies of the production activity in the industrial enterprise made with the Ratio Analysis technique show positive changes in the production and the sales by products, a positive rate of change of the increase in the number of personnel, a positive indicator of stock turnover, profitability higher than one, very good current liquidity.
- The study using the Strategic Position Analysis technique provides information that the company holds good positions in the sector in terms of market, production, personnel, economic and financial indicators. The most unfavourable is its marketing positioning, although it is close to the average positions in the industry.
- According to the Vulnerability Analysis, the supply and the cost are at risk, although the risk is not particularly tangible. This necessitates strategic moves to reduce the production costs in a sustainable manner.
- The Critical Success Factors Analysis technique used in the study of the company points to the need to reduce production costs and optimize profit.

The analyses of the environment show unequivocally that the selected company in which the Heuristic model for SMART management in a medium-sized industrial enterprise was implemented has a good competitive position, is in a good financial condition, realizes a sustainable market presence and market share which determines the indisputable presence of potential for expansion of the activity. However, the expansion of the activities requires a higher profitability of the production process. This would be possible if the production costs, which determine the cost, are reduced and the production is increased based on the innovations introduced in the company through the funding from the European Regional Development Fund. The «production - management» relationship in the industrial subject chosen for the testing of the model has to be studied using two main tools:

- A balanced system of indicators that shows the need to implement financial and non-financial indicators in the analysed company and, on this basis, to determine the efficiency as a function of indicators leading to a qualitative change in the financial and the organizational and technical state of the industrial enterprise;
- Brown's framework of process assessment which links the production process in the industrial enterprise with efficiency as an indicator that supports the sustainable production process and the development of the company.

The relational dependencies between the "management" and "production" subsystems in the industrial enterprise are identified on the basis of the studies and analysis made with the Balanced System of Indicators and the Brown Framework for measuring processes in the company in which the Heuristic Model for SMART management in a medium-sized industrial enterprise was implemented. (Table 2) The decomposition of the production process into operations in the studied economic entity highlights the following features:

- the operations are combined in parallel and sequentially;
- the average duration of each operation is 14.50 minutes;
- the movement of components and semi-finished goods is in parallel and sequential;
- the average time required for movement of components and semi-finished goods is 0.15 hours;

- theaverage machine setup time is 0.09 hours;
- the type of technological routes is in parallel and sequential;
- the average production time per product unit is 2.17 hours.

Table 2. Intersection points between the «production» and «management» subsystems in the industrial enterprise selected for implementation of the Heuristic Model for SMART management in the medium-sized industrial enterprise (adapted by the author by Temelkova, 2010)

Industrial Enterprise Selected for the Testing		
Subsystem	Elements	Intersection Points
Management	Strategic Management	planning organizing the coordination between production and management motivating staff reporting control
	Work Processes	processing and transfer of information
	Investments	efficiency
	Productivity	number of products by type
	Marketing	quality price market share
	Innovation	innovative technologies digitization
	Human Resources	remuneration
Production	Operating Management	planning of production organization of production, coordination and logistics production report control
	Production Process	operations time
	Logistics	supply procurement forwarding
	Technology	resource intensity
	Human Resources	remuneration

The analyses of the environment, the studies of the production process and its main components determine the mathematical foundation of the Heuristic model for SMART management in the industrial enterprise that was studied and analysed. The most important limiting conditions are generated on the basis of the studies and analysis of the company and its production in the previous stages of the model:

- limitations arising from the volume of the natural production (number of the j-type products)

$$\sum_{j=1}^{n} X_j^* \geq \sum_{j=1}^{n} X_j \quad [1]$$

or

$$\sum_{j=1}^{n} \frac{OH_{PSS}^*}{IPT^*} \geq \sum_{j=1}^{n} \frac{OH_{PSS}}{IPT} \quad [2]$$

- limitations arising from the monetised losses of technological time for each j^{th} product by processes of the n^{th} j-type product

$$\sum_{j=1}^{n} TLTT_d^* \times X_{jd}^* \times P_{LTT} \quad \sum_{j=1}^{n} TLTT_d \times X_{jd} \; P_{LTT} \quad [3]$$

- limitations arising from the monetised costs of material resources for the production of each j^{th} product by processes per unit of the j-type product

$$\sum_{j=1}^{n} TCMR_{dg}^{*} \times X_{jd}^{*} \times P_{Mg} \leq \sum_{j=1}^{n} TCMR_{dg} \times X_{jd} \times P_{MG} \quad [4]$$

- limitations arising from the monetised costs of energy per unit of product that is used to achieve the production of each j^{th} product by processes

$$\sum_{j=1}^{n} TEC_{d}^{*} \times X_{jd}^{*} \times P_{E} \leq \sum_{j=1}^{n} TEC_{d} \times X_{jd} \times P_{E} \quad [5]$$

- limitations arising from the monetised costs of labour for the production of a j-type product by processes of the n^{th} j-type product

$$\sum_{j=1}^{n} TLC_{d}^{*} \times X_{jd}^{*} \times P_{T} \leq \sum_{j=1}^{n} TLC_{d} \times X_{jd} \times P_{T} \quad [6]$$

- limitations arising from the monetised costs of operating the machines and automated and robotic devices used in the production of a j-type product by processes of the n^{th} j-type product

$$\sum_{j=1}^{n} TCMAR_{d}^{*} \times X_{jd}^{*} \times P_{MAR} \leq \sum_{j=1}^{n} TCMAR_{d} \times X_{jd} \times P_{MAR} \quad [7]$$

The studies, analyses and assessments of the state of the company and its production naturally lead to the conclusion that economic efficiency should be considered as a target criterion in the Heuristic model for SMART management in the studied industrial enterprise:

$$E = \frac{TR}{CP} \quad [8]$$

or:

$$L = \frac{TR}{CP} \rightarrow \max/\text{compromise} \quad [9]$$

or

$$L = \frac{Xj \,.P_p}{\sum_{j=1}^{n} TLTT_{d} + \sum_{j=1}^{n} TCMR_{dg} + \sum_{j=1}^{n} TEC_{d} + \sum_{j=1}^{n} TLC_{d} + \sum_{j=1}^{n} TCMAR_{d}} \rightarrow \max/\text{compromise} \quad [10]$$

The search for maximum or compromise values for efficiency requires the integration of heuristic elements into the Heuristic Model for SMART management in the company in which the model is implemented. They appear in the Matrix-based model for the relations between production revenue and resource intensity. On that basis the Heuristic model for SMART management in the specific industrial enterprise relies on high revenues and low resource intensity. The tree of alternatives in the industrial enterprise subject of the testing selects, as a heuristic tool, the following options:

- increased production capacity;
- increase in production;
- concentration;
- integration;
- diversification.

The software information technology foundation in the Heuristic model for SMART management in «the specific industrial enterprise finds expression in a model-based programme that calculates the efficiency in different situations and manages the other parameters in it based on the optimality criterion (Figure 3.). The governing parameters in the optimality criterion in the Heuristic model for SMART management in the economic subject, object of the testing, are the cost and the total revenue.

$$TR = [TR_{1,} TR_{2,} \dots TR_{v}]^{T} \quad [11]$$

$$CP = [CP_{1,} CP_{2,} \dots CP_{v}]^{T} \quad [12]$$

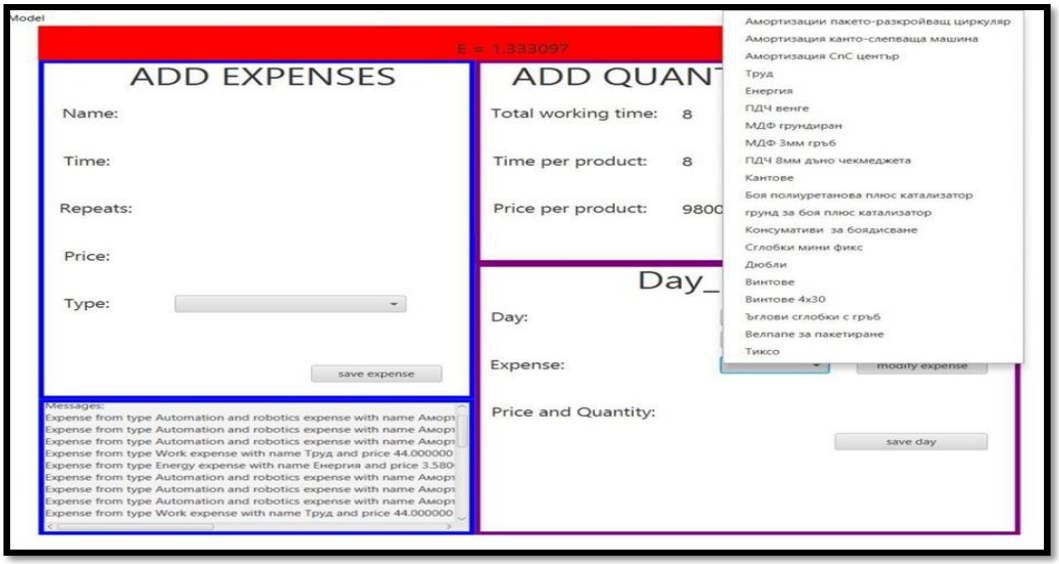

Figure 3. A software program of the Heuristic model for SMART management in a medium-sized industrial enterprise, tested in a specific economic entity – an operating window of the programme (developed by the authors)

Results and Discussion

The testing of the Heuristic Model for SMART management in the medium-sized industrial enterprise in a specific economic entity identifies certain changes within the entire production and financial life cycle. These changes are a kind of elastic chains that are connected and synchronized in the production programme of the particular company.

The implementation of the Heuristic model for SMART management in a medium-sized industrial enterprise determines the optimal management in the economic subjects applying it. The possibility of increasing the production capacity by 13% compared to 2021 and by 25% compared to 2020 was highlighted in the course of its testing in the specific industrial enterprise.

The application of the Heuristic Model for SMART management in a medium-sized industrial enterprise in the economic entity chosen for its testing creates real prerequisites for the development of the company in terms of the following strategic priorities:

- increase of personnel by 13%;
- cost reduction by 11% by:
- optimizing the storage and production capacity;
- optimizing the delivery and distribution channels and times;
- cutting technological resource losses by 8.1%;
- optimizing the technological equipment load by 35%;
- enhanced monitoring and control in the “bottlenecks” of the production process;
- reducing the production times by 8.7%;
- reducing the energy consumption by 9%;
- reducing material intensity by 20%;
- reducing time consumption by 17%;
- reducing the time for process management by 40%.

The significant changes provoked by the Heuristic model for SMART management in a medium-sized industrial enterprise in the company chosen for its testing caused qualitative changes in all value chains of the company and a quantitative change of the most important indicators of sustainability of the activities:

- productivity – it increased by 13% in that specific case;
- profitability – it increased from 0.26 to 0.30 after the testing of the model;
- efficiency – it increased from 1.32 to 1.67 after the testing of the model;

Conclusion

The application of the Heuristic Model for SMART management in a medium-sized industrial enterprise in a specific economic entity gives rise to the following more important conclusions assessing the results of the testing:

- The Heuristic model for SMART management in a medium-sized industrial enterprise is applicable to the industrial enterprises in all fields of production.
- The Heuristic model for SMART management in a medium-sized industrial enterprise can also be applied in the management of small industrial enterprises.
- The Heuristic model for SMART management in a medium-sized industrial enterprise provokes continuous organizational development in the industrial entities, as a result of which new organizational structures and new information reporting and information and communication systems are created.

The practical and applied usefulness of the Heuristic model for SMART management in a medium-sized industrial enterprise is based on the adaptation of familiar management approaches, technologies and tools to the qualitatively new requirements of the environment provoked by the development of Industry 4.0 (digitalization) and Industry 5.0 (heuristic practices and assessments). The management in the industrial enterprises that are subjects of the testing perceives the Heuristic model for SMART management in a medium-sized industrial enterprise as an opportunity to increase the efficiency and the added value of the activities in the industrial enterprises.

Maintaining efficiency in industrial enterprises requires continuous monitoring, analysis and assessment of their activities which means continuous application of the seven stages of the Heuristic Model for SMART management in a medium-sized industrial enterprise. Using its software-based model, this can be done automatically, with minimal labour and data entry time. Difficulties may arise when putting the model into operation due to the need for a large volume of production, technological, financial and other operational data.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Acknowledgements or Notes

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