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A model for aligning the features of the production process with the idea of sustainable development

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Abstract
The purpose was to develop and practically verify a model for aligning the characteristics of the production process with the idea of eco-development by identifying key factors related to technological capabilities and product competitiveness affecting the achievement of the goal and success of the enterprise. The study proposes a model approach to a multifaceted analysis of the key factors determining the construction of effective development strategies of industrial enterprises as a way to achieve the strategic goals of the enterprise in the long term. The study used a 3x3 linkage matrix divided into zones within which the results of surveys (carried out using a modified BOST questionnaire) were distributed, and statistical analyses were carried out to determine the level of importance of the considered factors from the area of technological capabilities and product competitiveness referring directly to the idea of sustainable development. The identified key factors referring to eco-development (optimization of the use of productive resources, design of a closed production cycle, in-house research and development) make up the development of new innovative sustainable technologies that will contribute to material savings and efficient use of energy, and thus have a positive impact on the environment. Verification of the developed model in a manufacturing company confirmed its usefulness in conducting data analysis for decision support.

Keywords
3x3 matrix, BOST survey, statistical analysis, process improvement, eco-development, sustainable development

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Introduction

Today, a significant dynamic of change is occurring both globally, regionally, and locally. There are noticeable changes occurring in the social, political, legal, organizational, and economic space in the form of, for example, intensifying competition or in the ways of conducting and improving business (Hummels & Argyrou, 2021; Wolniak, 2021). The market is also forcing the dynamic development of technology and engineering, particularly telecommunications and information systems, and has also created new opportunities for production and the improvement of currently used and the emergence of new concepts and management methods (Gavurova et al. 2022a; Ostasz et al., 2020). In response to turbulent market conditions, entrepreneurs are forced to monitor, analyze and perceptively receive information coming from the environment and use it for their own needs, as well as introduce innovative solutions to the products they offer (Pacana & Czerwinska, 2023; Malindzak et al., 2017). Businesses in line with the concept of sustainability are increasingly focusing on balancing technological, economic and social development plans with environmental constraints through changes in management processes and systems (Kelemen et al., 2019). As a result of these activities, the knowledge-based economy is increasingly taking shape, and the essence of the individual resources of the economic unit is also changing, with intangible capital gaining importance in the production enterprise (Wu et al., 2022; Vig, 2023).

Given the increasingly difficult conditions in the field of management or the dynamics of changes in the environment, the issue of creating adequate strategies for the development of economic activity through the identification of key success factors associated with eco-development does not lose relevance, on the contrary - it continues to open new cognitive and research platforms in the field of operation and development of production enterprises (Belas et al. 2022; Ulewicz & Blaskova, 2018). Creating the competitiveness of enterprises in the idea of sustainable development arouses discussions among executives, who see this as a conflict of goals, indicate concerns about increased risks and direct inquiries about factors of a strategic (critical) nature (Streimikiene, 2023; Pacana et al., 2014). The new perception of the issue of competitive factors of manufacturing enterprises, which determine the achievement of goals and success, is the result of a transformation of views on the main purpose of their operation - the negation of profit maximization. This position is justified by the fact that, as part of the competitive process of enterprises, the necessary growth of profits must also take into account such variables as the growth of the value of the economic unit, market share and its economic efficiency (Fedorko et al. 2018). The indicated economic goal should be realized with social sustainability in mind, which includes, for example, occupational health and safety, job creation and wage growth (Gavurova et al. 2022b). The realization of this goal should also take into account care for the environment through rational use of resources - reducing the resource intensity of mainly production processes (Olkiewicz & Wolniak, 2020; Staniszewska et al., 2020; Pacana et al., 2018). In organizations, various goals are achieved at a certain time and only at a certain level. In addition, not all goals can be maximized, with maximization of their value being a priority for different sets of interests as a future-oriented goal.

For manufacturing companies, one of the cornerstones in formulating short- and long-term goals and creating competitive advantage strategies was the European Commission's view articulated in the Europe 2020 Strategy: the European Union's strategy for growth and jobs (Drumaux & Joyce, 2020). This strategy emphasized the need for EU countries to act together to recover from the crisis and implement reforms related to globalization, ageing populations and the growing need for rational use of resources (Becker et al., 2020; Pasimeni & Pasimeni, 2016). There is also significant influence from the 2030 Agenda, which includes 17 Sustainable Development Goals and provides a strategy for world development until 2030 (Bouras & Sofianopoulou, 2023). These views assume that competitiveness will be a feature of a sustainable market economy (Shabbir, 2023; Pacana et al., 2024). Accordingly, the resource and factor allocation processes of enterprises located in the EU strategy are geared toward increasing the level of competitiveness with more efficient use of resources. As a result, three priorities are formulated: smart growth, which is based on knowledge and innovation (smart growth), sparingly manages available resources (sustainable growth), and is socially and territorially integrated (inclusive growth) (Khindasombatcharoen et al., 2022; Rybalkin et al., 2023).

Within the framework of the theory and practice of business development, the internal and external factors available to the entity play an important role, as well as the methods of identifying them and the criteria for assessing their level of relevance (Li et al., 2019; Gavurova et al. 2020; Ulewicz, R. et al., 2023). Several qualitative and quantitative methods for studying key success factors can be found in the literature. Among quantitative methods, the most commonly used is the survey method, in which the measuring instrument is a survey questionnaire (Dolata, 2019; Minarro-Viseras et al., 2005). Surveying is sometimes supported by a literature review (Castro et al., 2019). Another way of identifying key success factors, using a qualitative method, is based on the implementation of structured interviews with organizational executives who represent the industry or its various sectors (Sivakumaran et al., 2015). Multivariate statistical analyses are used to identify success factors and determine their structure. An example is the AHP -Analytical Hierarchy Process, a multi-criteria method for hierarchical analysis of decision-making problems. This method allows the decomposition of a multifactor and, thus, complex problem and the determination of the rank of individual factors (Nai & Mousrij, 2018; Toke & Kalpande, 2019). A method called meta-analysis is also used to study success factors in manufacturing companies. This method is often used as a systematic review of the literature, supplemented by statistical analysis, inference and final -summary (Ren et al., 2018; Song et al., 2008). In the field of success factor exploration, due to the significant number of analyzed companies and potential success factors, multivariate methods are increasingly used. These methods make it possible to hierarchize the multivariate data space while reducing its dimension to a dozen or even a few priority factors without making any initial assumptions. Among these methods, canonical analysis and classification, for example, are used in the subject under discussion (Schenhar et al. 2002).

Tab. 1. Methods for identifying, evaluating and selecting key success factors for manufacturing companies

Activity	Research group	Covered position in the context of the research subject	Representatives (literature items)
Identification of success factors	Survey	The research procedure was based on a standardized questionnaire with unit-scale responses, which yielded quantitative results on the relationship between project maturity and key success factors in project management.	Dolata, 2019
		In order to gather experience and knowledge from a wide range of industries, geographic locations, and a wide range of types and sizes of small and medium-sized companies, a survey of available practitioners from around the world was chosen as the most appropriate research method.	Minarro-Viseras et al., 2005
	Literature review and survey	Identification of key factors that influence success in Business Process Management (BPM) implementation through the implementation of literature review and practical experience of experts (survey).	Castro et al., 2019
	Survey and factor analysis and T-test	Identifying key success factors through factor analysis and one-sample t-tests to refine and rank success indicators based on the results of a survey of risk management practitioners in different types of Swedish corporations.	Yaraghi and Langhe, 2011
	Literature review and structured interviews with managers representing the industry or its various sectors	On the basis of the literature review and interviews with experts, the context of the main critical success factors of the automotive industry's emerging market entry planning processes was identified and operationalized with the corresponding key performance indicators.	Sivakumaran et al., 2015
Identification of success factors and assessment of the level of significance	Meta-analysis - systematic review of the literature supplemented by statistical analysis, inference and summary	A criterion evaluation system for assessing the environmental performance of shipping, including identification of key success factors, the definition of a criterion evaluation system (multiple criteria in the following five aspects: technological, economic, environmental, social and managerial), application of the analytical network process (ANP) (determination of the relative importance of these factors) and interpretive structural modelling (ISM) (causal relationship analyses).	Ren et al., 2018
		Literature analysis to gather data from existing empirical studies on new technology deployment (NTV). Using Pearson's correlation as an effect size statistic, a meta-analysis was performed to analyze the available studies and identify the most commonly studied success factors for NTVs, and measurement scales were determined.	Song et al., 2008
	Fuzzy AHP method	Using the fuzzy AHP method, which is a multi-criteria decision-making method that combines conventional AHP and fuzzy logic to weight and rank various performance criteria pertaining to the mining company, which made it possible to prioritize three key success factors, namely overall equipment efficiency, maintenance costs and asset condition.	Nai and Mousrij, 2018
	Literature review, AHP method, SAP-LAP analysis	In the study of key success factors and green production, a literature review was performed. The reliability of these factors was checked by calculating Cronbach's alpha. The analytic hierarchy process (AHP) pairwise comparison method was used to finalize the priority of key success factors after calculating internal consistency. SAP-LAP analysis and construct validation of three case studies were conducted.	Toke and Kalpande, 2019
	Multidimensional typological approach - canonical correlation and eigenvector analysis	The use of very detailed data and multivariate methods, such as canonical correlation and eigenvector analysis, made it possible to clarify all interactions between managerial and success variables and to include several developmental perspectives.	Schenhar et al. 2002

Analyzing Table 1, it should be noted that methods of exploring key success factors of organizations are still being used and created. However, methods of analyzing and interpreting the information obtained through the implementation of experimental studies have evolved. They are based on the use of advanced statistical methods that allow the analysis of larger sets of enterprises and a significant number of potential success factors, which in most cases leads to the determination of the relevance of the studied factors.

Taking into account the variety of characteristics and factors that occur and influence the conduct of business, it turns out that their ordering and hierarchization greatly facilitate managers and/or business owners to make effective management decisions in the development and maintenance of wiad market position (Vig, 2023; Czerwinska & Pacana, 2022). However, there is a lack of methods to analyze the success factors of manufacturing processes, i.e. micro-level analyses. According to the approach, by improving individual processes, the enterprise will be able to achieve the goals set for them and then the goals set for the entire enterprise.

Thus, the issue of improving industrial processes taking into account the premises of the concept of sustainable development, seems to be an important research problem. The purpose was to develop and perform practical verification of the model of alignment of the characteristics of the production process with the idea of eco-development by identifying key factors related to technological capabilities and product competitiveness affecting the achievement of the goal and success of the enterprise. The study proposes a modelling approach in terms of multifaceted analysis of key factors determining the construction of effective development strategies of industrial enterprises and the achievement of the strategic goals of the enterprise in the long term. As a result, the identified factors alluding to eco-development will influence the development of new innovative sustainable technologies that contribute to material savings and efficient use of energy and thus have a positive impact on the environment, ensuring a stable market position.

Method

In line with the idea of sustainable development, manufacturing companies have been confronted with the need to implement a number of changes relating mainly to economic, cultural and environmental development. The implication of sustainable production systems requires extensive knowledge to effectively adapt the principles of sustainable development in practice. Figure 1 shows the essence of the developed model for adapting the characteristics of production processes to the idea of sustainable development.

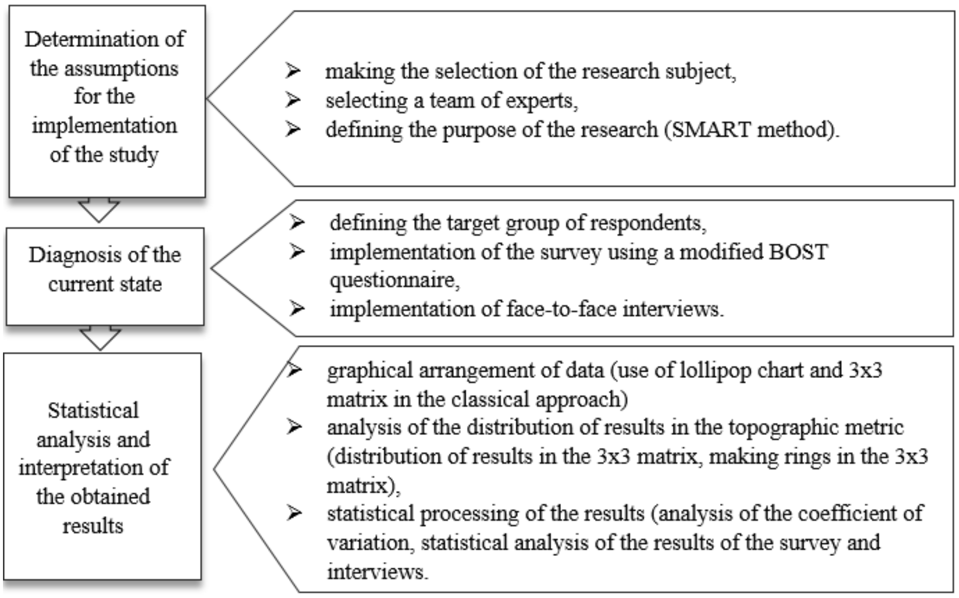

Fig. 1. Schematic representation of the idea of the developed research model

The model consists of three main phases, which include: defining the assumptions for carrying out the research, the diagnostic part and the statistical analysis of the obtained results. Within each of the main phases, three tasks were specified. A detailed description of the stages of model implementation is presented below.

Stage 1 - determination of the assumptions for the implementation of the study.

The model is directed first to the main/main production processes implemented in enterprises. Important in the context of the implementation of this phase of the study will be the characterization of the selected process and the specification of key process data.

The team of experts should include management personnel. These people should have extensive knowledge of the selected production process, as well as of the competing entities and the specific situation that prevails in the market and the industry in which the enterprise operates.

Determination of the purpose of the study should be done using the SMART method (an acronym for the characteristics of a properly constructed goal: (S - "specific", M - "measurable", A - "attractive", R - "realistic" and T- "time - based"). In the model, the SMART method, which is popular, was chosen to develop a correct goal. The method motivates action and allows for multifaceted considerations of the research objective. The SMART method is the best solution in the context of the correct construction of the research objective, as it supports the definition of the objective in a way that allows its implementation. Another important rationale for choosing the SMART method was that it helps adjust plans to changing conditions and opportunities and monitor progress.

One aspect that should be taken into account is the analysis of the production process in the context of applying the idea of sustainability objectives. Correctly built research objectives should allow diagnosis of the current state and analysis of the correlation: technological capabilities - market position while indicating future steps for effective implementation of the assumptions of the idea of sustainable development.

Stage 2 - Diagnostic part

The survey part of the study should include employees who have knowledge of the production process under study, the final product, the technology used and the market value of the enterprise. The group of respondents should be representative on the scale of the enterprise or industry.

As part of stage 2, survey research should be carried out using a modified questionnaire of the BOST method - an abbreviation of the author's name Stanislaw Borkowski. The survey should use a variant of the questionnaire designed for employees. This variant refers to a group of factors referring to selected Toyota principles (1, 2, 3, 4, 6, 7 and 14) and elements of the Toyota house model (roof of the house). The BOST method makes it possible to analyze the intangible resources of enterprises, such as customer well-being, product innovation, cooperation with cooperators, self-reliance and responsibility of employees, development of technology and nurturing of enterprise culture. In order to carry out a multifaceted analysis, the following factors were added to the standard questionnaire: size of the market offer, trust in relations with employees, quality of products, price of products, conduct of research and development, purchase of research and development. In accordance with the method, factors relating to sustainability were also included: optimization of production space, optimization of the use of productive resources, closed-loop design, design aimed at recycling and reuse of material resources, and safe and decent working conditions.

This should be followed by face-to-face interviews with praconics. This form of research should make it possible to obtain information useful for achieving the research objective. The topic of dialogues with employees should relate to the technological level and competitiveness of the product, taking into account the issue of sustainable development. The interview conducted will allow for better clarification of misunderstood issues in the early diagnostic step.

Step 3 - Statistical analysis of the results obtained

In order to organize the results from the diagnostic part of the survey, they should be illustrated using a lollipop-type chart indicating the relationship between a numerical variable and a categorical variable. Then, the distribution of pairs of analyzed factors should be presented in the areas of the modified 3x3 relationship matrix. In the original view of the 3x3 matrix, the X axis represents technological capabilities, and the Y axis represents market position. In the research being carried out, the Y axis is represented by product competitiveness (Figure 2).

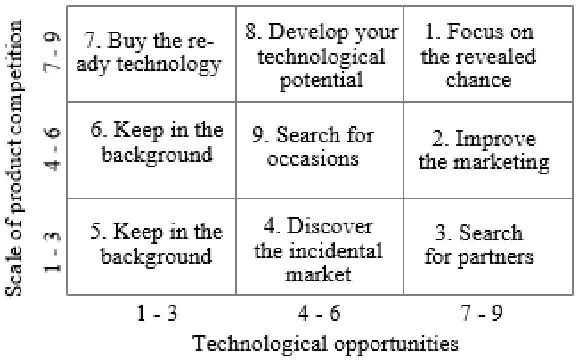

Fig. 2. Characteristics of the modified 3x3 linkage matrix

Each of the 9 specified areas of the 3x3 matrix testifies to a specific position of the studied product/product group/manufacturing plant and adequately indicates the development strategy. The biaxial approach of the 3x3 matrix provides a balanced assessment of factors and features. It is necessary to strive to achieve field 1. In the modified version of the linkage matrix, this field indicates the recommendation of a development strategy with special attention to the use of technological capabilities and competitive features in achieving success with care for the environment in accordance with the concept of sustainable development. The use of the standard version of the 3x3 linkage matrix can be seen in the study (Lowe, 1995). The use of the matrix in a transformed version can be observed in works related to technology-product analyses (Klimecka-Tatar and Ingaldi, 2020; Borkowski et al., 2014; Borkowski et al., 2012).

The next step is to analyze the areas of the 3x3 matrix, understood as distinct metric spaces, and the dominant pairs of outcomes located in them regarding technological capabilities and product competitiveness. In each of the 9 areas of the matrix, the centre of the circles and rings are considered to be the dominant points in the area. The radii of the rings are 1. The value of a radius of 1 indicates the centre of a particular area of the matrix.

The study also analyzes the coefficient of variation (CV), which is used to compare the variation in the pairs of factors analyzed. This coefficient is a relative measure and, therefore, dependent on the size of the arithmetic mean. It is a type of measure that describes the relationship that exists between individual distributions that differ from each other and from the values of the features around the central values - in relation to the rings created in the individual fields of the matrix, we can talk about the features located around the centres of the rings. The level of variation in the distribution of factor evaluations (technological capabilities and competitive features) within the 3x3 linkage matrix is analyzed.

Method verification and results

The foundry industry belongs to the heavy industry, which, for the most part, produces for the needs of other industries and less frequently for consumers. As part of the implementation of the concept of sustainable development, this industry is obliged to undertake radical modernization. Verification of the developed model was carried out in one of the foundry companies located in the southeastern part of Poland, where the foundry industry is particularly popular. The company manufactures cast aluminium alloy products mainly for the automotive, aerospace, medical and railroad industries.

Stage 1 - defining the assumptions of the research implementation.

The verification of the developed model was performed for the oil pan casting, the manufacturing process of which was the subject of the study. The oil pan casting is made from AlSi10Mg alloy and is used in light vehicles. This product is one of the basic components of the drive unit, which is responsible for storing the engine's lubricating oil. The product selected for analysis is one of the mainly manufactured products in the enterprise.

A task force was established, consisting of the head of the technology department, the quality control manager, the product marketing manager and the product auditor. The selection of members of the task force was made taking into account the relevant competencies that were necessary to carry out analyses related to technological opportunities within the framework of the selected process and the competitive aspect of the product - the oil pan, with particular regard to the idea of sustainable development.

The purpose of implementing the model is to analyze data on the technological capabilities of the oil sump production process and the characteristics of the product, which are aspects of competitiveness. An in-depth diagnosis and analysis of the factors affecting the subject of the study will make it possible to eliminate the critical variables that generate disruptions in the process and will allow effective development measures to be taken in the context of ensuring a high level of competitiveness, taking into account the sustainability feature of the product.

Stage 2 - Diagnostic survey

The questionnaire survey included management-level employees who were responsible for monitoring and improving the analyzed manufacturing process and finished product. Due to the pilot nature of the work being carried out, 30 employees participated in the survey, accounting for 54% of management. The research took place in the fourth quarter of 2023.

The question before the respondents in the survey was, "What factors determine the concept of development of the oil sump production process?". Employees were asked to rate the listed success factors on a scale of 1-9 (1 - the least important factor, 9 - the most important factor). The factors were divided into two areas: technological capabilities (product innovation, employee self-reliance, employee responsibility, technology development, optimization of production space, optimization of the use of productive resources, closed-loop design, design aimed at recycling and reuse of material resources) and factors relating to the competitiveness of the product (customer interest, cooperation with cooperators, trust in relations with employees, preservation of culture in the company, size of the market offer, product quality, product price, in-house research and development, purchase of research and development).

The survey was supported by face-to-face interviews, which were conducted with people employed in managerial positions. The implementation of the face-to-face interviews was intended to address respondents' doubts about the issue raised in the survey and to provide a broader view of the process under study. The direct interviews also addressed the following issues: efficiency in the management and use of available resources, profitability and competitiveness of the production process, and ensuring compliance of the activities undertaken with the concept of corporate social responsibility. The topic of long-term development strategies closely related to the implementation of aspects related to environmental protection, social interests and ensuring positive relations with various stakeholder groups was also raised.

Stage 3 - Statistical analysis of the results obtained

The information gathered in Stage 2 of the model was arranged to compile a numerical characterization of the analyzed factors regarding technological level and competitiveness. The lollipop chart shows the distribution of evaluations of the analyzed factors (Figure 3).

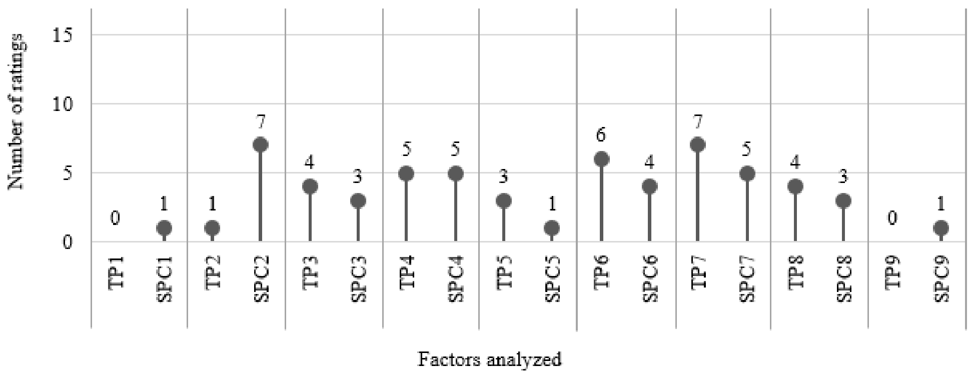

Fig. 3. Assessment of the level of significance of the analyzed factors from the categories of technological capabilities (TP) and product competitiveness (SPC)

Figure 3 is a descriptive account of the ratings that respondents gave to the surveyed factors in the technological capabilities (TP) and product competitiveness (SPC) categories. Respondents considered SPC2 - product quality and TP7 - optimization of the use of productive resources to be the most significant.

The obtained ratings of the pairs of factors were then included in a 3x3 relationship matrix. This inclusion takes into account the percentage and numerical indications of the obtained evaluations (Figure 4).

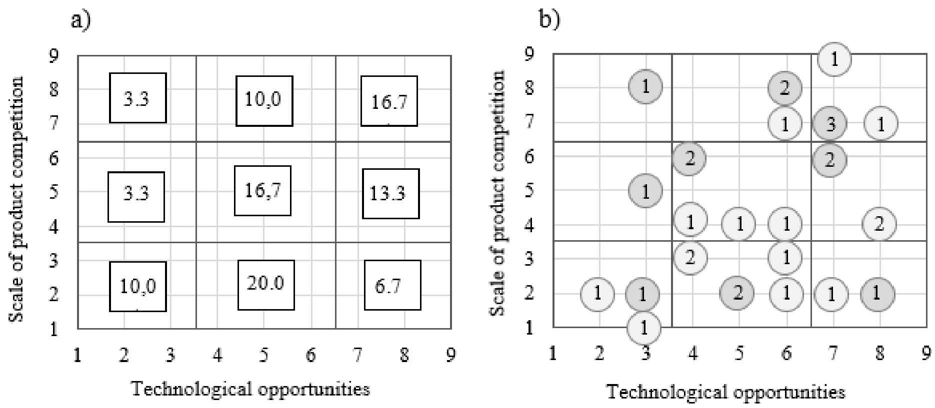

Fig. 4. The structure of the importance of evaluations of pairs of factors from the scope: technological capabilities (TP) and product competitiveness (SPC) in terms of a) percentage and b) numerical, taking into account the focal points of each sphere of the matrix of relations

Within the linkage matrix, zone 4 (strategy: discover the incidental market) has the highest concentration of factor pairs. 20.0% of feature pairs were located within this zone. The largest number of surveyed employees gave ratings in the range of 4 - 6 for the technological capability factors, while ratings in the range of 1- 3 were given for factors indicative of product competitiveness. Not much smaller numbers of factors were located within zones 9 (strategy: search for occasions) and 1 (strategy: focus on the revealed chance). 16.7% of factor pairs were indicated in these zones.

With regard to the obtained results of the survey, within the production process, the product should be made more attractive - activities concerning the creation of product competitiveness should be intensified. To this end, the company should increase the efficiency of activities, such as a range of product prices, and pay special attention to the interests of the customer. Acting in two ways - in the area of technological capabilities, further optimization of the use of production resources should be carried out, and work should be undertaken on designing a closed production cycle. Increasing the level of activity within the indicated areas will make it possible to move the results towards the desired strategy located in Zone 1.

The distribution and structure of factor pair ratings within the zones of the linkage matrix were also analyzed. Within each zone, dominant points were identified, which are the centres of circles whose radius is equal to the value of 1. The centres of the circles are marked in the darkest colour in Figure 4(b). When there are equal values of points in a specific zone, the centre of the circles was considered to be the score close to zone 1, i.e. the scores on the x and y axes with the largest values. The rings with the centres defined in Figure 4(b) were then distributed within the spheres of the 3x3 relationship matrix. This procedure is illustrated in Figure 5.

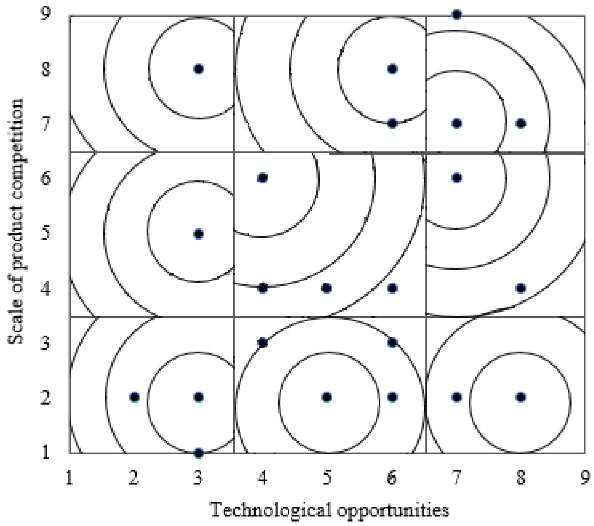

Fig. 5. Distribution of rings in the different spheres of the 3x3 link matrix

The percentage of individual pairs of factor evaluations that fell within the defined rings was also analyzed. This analysis is presented in Table 2.

Tab. 2. Percentage distribution of the set of points within the rings created based on the linkage matrix

Ring structure in a 3x3 linkage matrix		Zones of the 3x3 link matrix								
		1	2	3	4	5	6	7	8	9
Distribution of grade pairs within rings within 3x3 matrix zones	0 ≤ r < 1	60	50	50	33	33	100	100	50	25
	1 ≤ r < 2	20	0	50	17	67	0	0	50	0
	2 ≤ r < 3	20	50	0	50	0	0	0	0	50
	3 ≤ r < 4	0	0	0	0	0	0	0	0	25

Table 2 indicates that zones 1, 4 and 9 show the highest level of dispersion of evaluations of the analyzed factor pairs. At the same time, these are the zones to which the largest number of factor pairs were assigned on the basis of assessments - these zones should have the greatest impact on the creation of the process development strategy. Within zones 6 and 7, one pair of factors each was located, which represents the marginal value of the assessment in the context of planning development activities.

In order to compare the level of variation in the studied pairs of factors from two different distributions, one measure of statistical analysis was used - the coefficient of variation, which determines the ratio of variation of the standard deviation from the mean.

Based on the percentage distribution of the set of scores within the rings created on the basis of the linkage matrix, the values of the coefficients of variation of the importance ratings of pairs of factors (technological capabilities and product competitiveness) were determined (Table 3).

Tab. 3. Level of homogeneity of test results within the zones of the 3x3 linkage matrix, including ring division

Zone of the matrix	1	2	3	4	5	6	7	8	9
Value of the coefficient of variation of the percentages of pairs of factors	57	0	0	40	34	0	0	0	35
Number of non-empty rings	3	2	2	3	2	1	1	2	3

Within the analyzed zones distinguished based on the linkage matrix, the values of the coefficient of variation range from 0 to 57. Five zones (zone: 2, 3, 6, 7, 8) are characterized by homogeneity - no variation in features. There is a difference in the dispersion of values within the remaining zones. Zones 4, 5 and 9 show average (medium) variability, while zone 1 shows strong strong variability.

The use of the coefficient of variation values of the sets formed based on the linkage matrix makes it possible to identify the real strength of the dispersion of factors within each sphere. On this basis, the grading of the zones of the 3x3 matrix was performed, and their ranking was made:

$$(2, 3, 6, 7, 8) < 5 < 9 < 4 < 1 \tag{1}$$

The classification of the matrix spheres was made on the basis of the principle of interpretation of the CV coefficient used, according to which the value of the coefficient is reduced the better. The set of numbers of the matrix spheres placed in parentheses indicates equal (the same) values of the indicator. The research procedure made it possible to observe a significant level of agreement between the accepted positions of respondents in assessing the impact of the analyzed factors of the technological sphere and product competitiveness on the success of the subject of the research.

The most important factors in terms of development, improvement and building a stable position are pairs of factors located in zone 1, followed by zones 4 and 9. In these zones of the 3x3 matrix were such factors as:

- Zone 1: development of technology (a factor from the technological capabilities category) and attention to customer interests (a factor from the product competitiveness category),
- Zone 4: optimizing the use of productive resources (a factor from the technological capabilities category) and the price of products sold (a factor from the product competitiveness category),
- Zone 9: designing a closed production circuit (a factor from the technological capabilities category) and in-house research and development (a factor from the product competitiveness category).

Implementation of development work closely related to the listed factors will contribute to the company's goal of maintaining a leading position in the market. Embracing a strategy based on the presented development direction will allow the enterprise to be placed in the desired zone of the 3x3 matrix - the zone indicating the "Search for occasions" strategy.

The group of factors considered to have a significant impact on achieving success includes those that closely correspond to the idea of sustainable development (optimization of the use of productive resources, design of a closed production cycle, in-house research and development). These activities add up to the development of new innovative sustainable technologies that will contribute to the saving of materials and the efficient use of energy, thus having a positive impact on the environment.

The proposed author's model can be used in manufacturing enterprises as a method to help managers and owners of the organization make effective and adequate management decisions on building an effective development strategy and maintaining a prominent market position. Each enterprise itself selects a group of appropriate experts (respondents). It should be borne in mind that the results of the analysis conducted using the model will be dedicated to a specific entity. Developed on the basis of the identified key factors of success, the development strategy is not necessarily suitable for another manufacturing enterprise with similar characteristics. The proposed model for analyzing technological data is characterized by a broad application dimension.

Conclusions

The success of manufacturing companies in the market depends largely on their efficiency, which is influenced by various factors, both related to their core business and those in their environment. In today's market economy, multifaceted improvement and optimal development regarding technological capabilities and product competitiveness, taking into account the concept of sustainable development, play an important role. At the same time, if the decisions made are to meet the criterion of optimality, they should be considered together. Therefore, the goal was to develop a model for adapting the characteristics of the production process to the idea of sustainable development by identifying key success factors from the area of technological capabilities and product competitiveness related to eco-development.

The developed model uses a 3x3 linkage matrix divided into zones within which the results of the survey (made using a modified BOST questionnaire) were distributed, and statistical analyses were carried out to determine the level of importance of the factors under consideration from the area of technological capabilities and product competitiveness referring directly to the idea of sustainable development. The obtained ranking of the importance of pairs of factors indicated the aspects on the basis of which the company's development strategies should be built. Factors referring to eco-development (optimization of the use of productive resources, design of a closed production cycle, in-house research and development) make up the development of new innovative sustainable technologies that will contribute to material savings and efficient use of energy and thus have a positive impact on the environment.

Verification of the developed model in a manufacturing enterprise confirmed its usefulness in conducting data analysis in terms of supporting decision-making processes regarding internal and external space and making the pace of development more dynamic.

The presented research model is characterized by universality and a wide application dimension. It provides a tool that can be used to support decision-making processes based on the identification of success factors in spatial terms. The results of such analysis can be used by various types of business entities.

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