processes

MDPI

Article

Method of Analyzing Technological Data in Metric Space in the Context of Industry 4.0

Karolina Czerwińska and Andrzej Pacana *

The Faculty of Mechanical Engineering and Aeronautics, Rzeszow University of Technology, 35-959 Rzeszow, Poland; k.czerwinska@prz.edu.pl

* Correspondence: app@prz.edu.pl; Tel.: +48-17-8651390

Abstract: The purpose of this article was to develop a method of analyzing the manufacturing process with variables indicating product competitiveness and technological capabilities in metric space as a cognitive source. The presented method will facilitate the identification of key development factors within the manufacturing processes that have the greatest impact on the adaptation of the manufacturing enterprise to Industry 4.0. The presented method of manufacturing process analysis integrates a number of tools (SMART method, brainstorming, BOST analysis, 3 × 3 metrics) that enable the implementation of statistical analysis. The model developed makes it possible to apply known mathematical methods in areas new to them (adaptation in the manufacturing area), which makes it possible to use scientific information in a new way. The versatility of the method allows it to be used in manufacturing companies to identify critical factors in manufacturing processes. A test of the developed method was carried out in one of the foundry enterprises, which allowed us to build a series of importance factors affecting effective production management. The methodology is addressed to the management of manufacturing enterprises as a method to assist in analyzing data and building (on the basis of improved manufacturing processes) a competitive strategy.

Keywords: 3 × 3 matrix; BOST survey; statistical analysis; process improvement; quality 4.0; industry 4.0; mechanical engineering

Citation: Czerwińska, K.; Pacana, A. Method of Analyzing Technological Data in Metric Space in the Context of Industry 4.0. *Processes* **2024**, *12*, 401. https://doi.org/10.3390/pr12020401

Academic Editors: Chia-Nan Wang, Nhat Luong Nhieu, Phan Van-Thanh and Hector Tibo

Received: 17 January 2024
Revised: 15 February 2024
Accepted: 16 February 2024
Published: 17 February 2024

1. Introduction

Both increasing globalization and changes in the area of competition and economy determine the need to undertake changes in the management of a production enterprise. For this reason, enterprises, which are fundamental subjects of the economy, are increasingly required to have the ability to adapt their management methods and work organization to the thoroughly transforming conditions of their operation [1,2]. The ability to adapt to prevailing conditions in the environment (the dynamics of change, the structure of the organization, the complexity of processes) and the requirements of the market economy affects the results of operations and the development prospects of production facilities. The adaptation of enterprises becomes apparent in the form of implementation of various restructuring and innovative projects. The economic system creates specific operating conditions for organizations that enable enterprises to achieve their development goals. At the same time, the market economy places demands and challenges on guaranteeing the relative stability of operations [3–5].

As part of survival and continued stable operation in the market, increased development is a necessary process leading to changes in the structure and level of components of the enterprise. Development is determined by internal and external factory determinants of market success [6,7]. Internal factors are considered to be those that can be directly influenced by the enterprise. This group of factors determines the development of the enterprise. Among the internal factors, the most common are intellectual and capital-based factories [8]. On the other hand, conditions and external factors are those which the enterprise has little opportunity to influence. Intrinsic factors are defined as the broadly defined environment of the enterprise. From the environment, the enterprise meets its needs while, at the same time, drawing on its resources [9–11].

Businesses operate in a certain external environment, that is, in a specific area in conjunction with other organizations and with the state. The environment shapes opportunities and possibilities but also creates constraints and places requirements [12]. On the other hand, it also happens that businesses indirectly (through their functioning) influence the external environment and shape its nature to a greater or lesser extent. Such a situation occurs in the case of business entities, or a group of entities characterized by high bargaining power; their decisions can trigger changes in the entire sector [13,14]. The external environment of modern companies is transforming into an increasingly volatile and complex one, and at the same time, it forces rapid and ruthless adaptation to new conditions. As a result, the level of dependence of companies on external conditions is increasing. Organizations wishing to operate in the market and ensure competitive advantage should have the ability to flexibly adapt to market changes. The need to undertake adequate and adaptive activities changes the scope and logic of organizations and the way they are managed and improved [15]. In the literature on the subject [16–18], an approach is encountered which testifies to the fact that actuating enterprises are oriented to conform to the changes that take place in the internal and external spheres, which has not only become a determinant of the survival of economic entities but also affects both the bluntness and level of their development. Only this type of adaptive enterprise will allow for the long-term multiplication of capital value and the realization of one of the main goals of the essence of the functioning of companies, namely, the maximization of market value, which, in the long term, allows for profit maximization [19]. Such a state of affairs is possible thanks to continuous restructuring changes, which enable the implementation of important transformations in the organizational, technical, production, and economic planes. Development processes translate into an increase in the efficiency of the undertaken activities, which directly shapes the rate of their creation of enterprise value and its market position [20]. There are many benefits in terms of developing competitiveness with the initiation of Industry 4.0.

The fourth-generation industry covers the entire value-added chain with its scope. As a result, it requires new strategies and business models, and at the same time, it implies the integration of industrial areas with the use of information technology [21,22]. Industry 4.0 promotes efficiency improvements, cost reductions, and shortens test phases and production. It makes it possible to extend the useful life of products. It makes it possible to produce individual pieces of products without limiting profitability to mass production only [23]. Industry 4.0 is supposed to be a guarantee for maintaining competitiveness in countries with high wages, energy conservation, and an aging population, while allowing manufacturing companies to adapt their offerings to the dynamically changing needs of the market and the demands of high quality [24,25]. However, before the operation of enterprises in accordance with the idea of Industry 4.0 develops its full potential and begins to bring positive effects to the economy, it will be crucial to look for new, progressive solutions. These solutions should concern the management of the organization, especially the technical area through effective control of the internal factors that shape the market position [26,27].

The purpose of the developed model was to identify the factors with the greatest impact on the technological capabilities and market position of manufacturing companies in the context of the idea of Industry 4.0 through the analysis of technological data within the metric space. The methodology used a 3 $\times$ 3 matrix within which the results of surveys were located, and statistical analyses were performed in order to propose a new use of scientific information and to realize in-depth analyses to support the management of the technological and organizational space. The proposed analysis model is characterized by a wide application dimension. It can be implemented in any manufacturing enterprise whose development intentions are geared towards Industry 4.0 concepts. Integration of the model in a manufacturing enterprise allows us to identify the most important factors in the context of the development and success of the enterprise. This procedure will make it possible to develop effective plans for the development of the enterprise in the context of the idea of Industry 4.0. The next section of this study performs a literature review, which was carried out as part of our identification of the research gap in the topic under consideration. Section 3 describes the concept and assumptions of the developed data analysis model in metric space. Section 4 presents the verification of the model and its results. Section 5 is devoted to the summary of the study.

2. Literature Review

Adequately carried out management in specific internal and external conditions makes it possible to ensure a high level of competitiveness of the enterprise, which ensures a stable market position [28]. The competitiveness of a specific enterprise is most often studied in comparison with other comparable companies operating within the same sector. In the present approach, the aspect of competitiveness is understood as the result of the actions taken, which are related to customer acquisition [29]. Competitive superiority can be closely related to a well-thought-out and realistic strategy of technical development adequate to the concept of Industry 4.0 [30,31].

Constantly changing trends and market conditions force companies to seek new and progressive solutions in the field of organizational management [32], especially in the technical area through effective control of the internal factors shaping market position [33]. The management of enterprises focused on the implementation of developmental changes increases the possibility of implementing revolutionary solutions, resulting in increased competitiveness, often in a positive way. For this reason, various methods of analyzing the level of competitiveness are proposed in the literature. These methods are based on the analysis of multi-criteria indicators [34,35], the integration of several methods (historical method, content analysis, system analysis, formalization method) [36], and rough set methods used to assess the benefits of resources [37]. Proprietary methods relating to multi-faceted competitive analysis are also being developed. An example of this is the hybrid GIANN method, which combines multi-attribute utility theory with the concepts of entropy and information extraction and computational modeling via a multi-layer perceptron artificial neural network [38]. Models directed at recognizing the correlation between the technological level and competitive success of companies are also being developed [39]. Ejaz proposed a theoretical linear model identifying the digital technologies used, which have been shown to be a source of manufacturing competitiveness. This study sheds light on the limitations of measuring or defining the competitiveness factor at the company, regional, or national level. With regard to methods for measuring the level of competitiveness, it also distinguishes between methods that target cross-enterprises of a certain size, an example of which is a concept aimed at small manufacturing companies, which combines a context-free perspective with the contingency theory of quality management (Baldrige's quality excellence model) [40]. The indicated concept allows for the identification of internal factors with a significant impact on the competitiveness of an enterprise. The indicated methods refer to analyses based on internal factors.

With regard to external factors, methods for analyzing the level of competitiveness and market position most often involve market (marketing) research [41,42], and sometimes, marketing research is combined with comparative analysis [43]. Map-based methods (a novel dynamic mapping platform) are also proposed for analyzing changes in competitive positions [44]. Authors Fluhrer and Brahma [45] also present a concept of competitive level positioning in which data are analyzed using qualitative structuring. There is also research on hybrid brand positioning strategies undertaken to identify the most effective strategy [46].

Based on the literature review, studies on technology data analysis and competitive level analysis were grouped. The extracted areas are shown in Table 1.

Table 1. Research areas of technological data analysis and level of competitiveness.

Factor	Group	Covered Position in the Context of the Subject of the Study	Representatives (Literature Items)
Internal and external factors	Comparative studies	Examined against other comparable companies operating within the same sector. Lack of separation of factors.	Campos, T.L.R., Nunhes, T.V., Harney, B., de Oliveira, O.J. [22]
	Analyses of multi-criteria indicators	Expert analysis of the results obtained through the use of multi-criteria indicators that demonstrate the commercial success and competitiveness of the company.	Ginevicius, R., Gedvilaite, D., Stasiukynas, A., Suhajda, K. [34]
		Integration of macro and micro indicators at the level of the balanced scorecard (an analytical tool) in order to make management decisions about business operations and the level of competitiveness.	Datsenko, G., Kotseruba, N., Krupelnytska, I., Kudyrko, O., Lobacheva, I., Otkalenko, O. [35]
Internal factors	Integrating several methods of analysis	The following methods were used: the historical method and the content analysis method were used to examine the theory of enterprise development; the system analysis method was used to substantiate the conceptual vision of commercial enterprise development; and the formalization method was used to create a core model of enterprise development. The goal was to identify internal key determinants of competitiveness.	Hrosul, V., Zubkov, S., Mkrtchyan, T. [36]
	Approximate set methods	The weight of each evaluation indicator was determined with the application of significance in rough set theory, using the linear weighting method to determine the final result. It then systematically explains the main ideas and methods of rough set theory in evaluating favorable resources of enterprises.	Li, Z.G., Lou, W.F., Li, Y.S. [37]
	Neural networks	Consideration of multi-attribute utility theory with the concepts of entropy and information extraction, and computational modeling through the multi-layer perceptron artificial neural network.	Schaefer, J.L., Tardio, P.R., Barierle, I.C., Nara, E.O.B. [38]
	Linear models	A linear model identifying the digital technologies used which have been shown to be sources of manufacturing competitiveness.	Ejaz, M.R. [39]
	Context-free perspective combined with contingency theory of quality management	Using a pooled cross-sectional design and structural equation modeling to test the validity and reliability of the Baldrige model to measure quality management practices.	Parast, M.M., Safari, A., [40]
External factors	Market (marketing) research	Survey research using a proprietary questionnaire.	Anawade, Pa., Sharma, D.S. [41]
		A novel influence analysis technique called Grey Influence Analysis (GINA), which can be used to analyze the influence relationships between a set of factors when there are a large number of responses.	Rajesh, R. [42]
	Combining marketing research with benchmarking	Factor analysis, cluster analysis, and regression analysis were used.	Lin, S., Xu, S.Y., Liu, Y., Zhang, L.Y. [43]
	Dynamic mapping	EvoMap—a novel dynamic mapping framework that identifies company trajectories from high-frequency and potentially noisy data.	Matthe, M., Ringel, D.M., Skiera, B. [44]
	Competitive level positioning	Analyzed data using qualitative structuring, resulting in a newly developed and empirically based typology of SME positioning strategies.	Fluhrer, P., Brahm, T. [45]
		Exploring hybrid brand positioning strategies in emerging markets based on two positioning elements: brand country of origin (COO) and brand globality.	Hong, R.Y., Zhang, Z., Zhang, C., Hu, Z.H. [46]

Previous work has mainly relied on the survey method, on multi-variate competitive analysis, on multi-attribute utility theory, and even neural networks. The aforementioned methods, although beneficial, require preparation for their application. The integrated methods proposed in the model have the advantage of being easy to apply. Through this, the potential area of application (wide implication range) can be increased.

So far, the combination of methods used in the developed model has not taken place, and the advantages that characterize the integrated methods allow us to assume that the proposed model will be effective for companies using it.

The research highlighted the division of methods into two main groups: methods that are mainly based on the analysis of internal factors; and methods whose analysis is based on external factors. It is relatively rare to find methods that refer to internal and external success factors in terms of competitiveness. The realized analyses led to the identification of the gaps which will be considered in the study: (1) the lack of a model that integrates internal and external factors in the area of technological capabilities and market position (Industry 4.0) in a single model; (2) the lack of a model that recognizes the key factors (internal and external) underpinning the success of a manufacturing enterprise; and (3) the lack of a model that, based on an analysis of the internal and external factors of a manufacturing enterprise, indicates a development strategy to increase the competitiveness of the enterprise. The study presents a structured model for proceeding with the analysis of data in the metric space on the degree of utilization of technological capabilities and competitiveness indicative of market position in the context of Industry 4.0. The presented model supports the management and development processes of enterprises and, at the same time, fills the identified research gaps.

3. Method of Data Analysis in Metric Space

The market position of manufacturing plants is influenced by the level of technological sophistication and innovation, as well as the quality of finished products. Therefore, a key issue in the context of effective management is data analysis, particularly the relationship between the technological capabilities and competitiveness of products. Figure 1 shows the assumptions of the developed data analysis model for adapting the production process to the requirements of Industry 4.0.

The developed model was divided into three steps: survey preparation, diagnostic testing, and statistical analysis. The individual steps of the method are as follows:

Stage 1—survey preparation

Given the distinctive features of the tools used in the method of data analysis in metric space, the main production process carried out in a manufacturing company should be considered the proper subject of the study. In addition, it is necessary to identify the key data for the study from the selected process.

The selection of a team of experts is an important step in the implementation of the presented method of analysis; it means the selection of people responsible for the implementation of the presented method in the context of obtaining the intended results. Individual members of the expert team should be selected from the management team. The members of the team should have experience and a wide range of knowledge regarding the selected subject of research, as well as competition and the situation in the market within which the company operates.

In the framework of the implementation of the developed model, it is recommended to define a research objective that will be linked to the results of the analysis. The definition of the goal should be based on the SMART technique—one of the most effective techniques for properly defining the desired results and the path to achieve them. The name SMART is an acronym referring to the five key characteristics that a well-defined goal should meet (S—"specific"; M—"measurable"; A—"attractive"; R—"realistic"; and T—"time-based") [47,48]. Setting goals in accordance with the SMART principle allows you to start implementing them right away, to stay motivated to see your actions through to the end, and to be able to easily assess progress and accurately determine when the established goal has been achieved. The SMART principle folds into a precise approach to defining the study's objectives, motivates action, and further prompts multi-faceted consideration of the study's purpose [49,50]. One of the planes is the analysis of production processes in the context of the implications of the Industry 4.0 concept. The definition of an adequate research objective (using the SMART technique) will facilitate the realization of the analysis of the current state of affairs in the relationship between technological capabilities and market position and will make it possible to indicate further courses of action in terms of effective adaptation to the Industry 4.0 concept in the diagnosed development conditions.

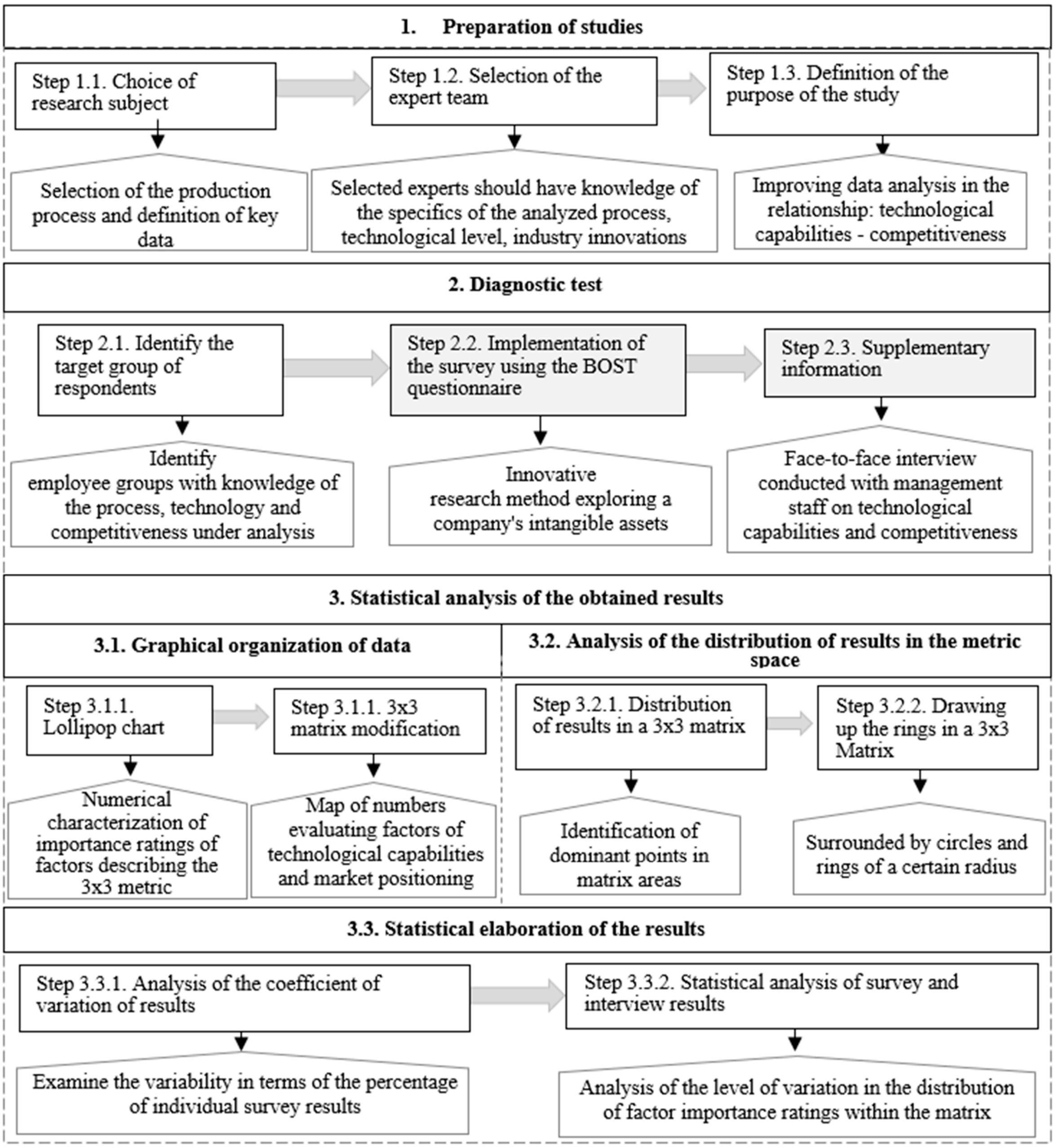

Figure 1. Concept of the method of data analysis in metric space.

The SMARTER method can also be used to identify and build a valid survey objective. This method is a development of the SMART method by including additional features (E—"exciting"; and R—"recorded") that the study objective must meet. Another modification of the SMART method is the SMART UP method, which indicates that the stated goal, according to the acronyms, should be U—"under control" and P—"positive" [48].

In the study, the SMART method was chosen to build a correct objective due to its considerable popularity in scientific works. This method is the best choice in the context of defining the goal of the study because it supports setting the goal in a way that allows it to be achieved. An important determinant of our choice of the SMART method was also the fact that this concept helps monitor progress and adjust plans in response to changing conditions. In addition, the method clearly indicates what the goal should be (meeting 5 characteristics: "specific" "measurable", "attractive", "realistic", and "time-based"). Related methods, which are an extension of the SMART method, are only a development of it, which are not required in the context of the research topic undertaken.

Stage 2—Diagnostic survey

Managerial staff of the production department, technology department, quality control department, and product marketing department were selected for the survey. A total of 28 people participated in the survey. The group of employees is responsible for the control and improvement of the studied extrusion process and product—the suction manifold. The indicated number of respondents is due to the fact that the research carried out within the framework of the study is a pilot study and concerns the selected manufacturing process. The enterprise employs about 1300 people and the group of respondents thus represents 21.54% of the managerial staff associated with the studied production area.

The survey was conducted in the fourth quarter of 2023. The survey was mandatory, and the return rate was 100%. The survey questions were subject to validation.

We carried out a survey using the BOST (acronym from the author's first and last name—Stanislaw Borkowski) method in the employee version [51]. The employee version takes into account a set of factors relating to the elements of the Toyota house roof and principles 1, 2, 3, 4, 6, 7, and 14 [52]. The model developed includes Toyota's first management principle, which indicates that management decisions should be based on a long-term philosophy, even at the expense of short-term financial goals [53,54]. The use of the BOST method was considered the best solution for further research because the model allows for the collection and further analysis of data using a standardized questionnaire in which the questions relate to spheres that coincide with those studied within the implications of the model (technological capabilities and market position of the company). One aspect that confirms the best choice of this method is the factors included in it; these allude to providing the best quality products while implementing processes in the shortest possible time, as well as at the lowest cost, which can be considered important aspects in terms of achieving success.

The benefit of the BOST method is its transparent nature and the speed of its implementation. The usefulness of the BOST method is also manifested in its ability to use a standardized set of competitive factors in the study, which contributes to the success of the research.

The BOST method sets the direction for further research by determining the factors describing the Toyota management principle 1 in the context of determining their impact on the technological capabilities and market position of the enterprise against the background of the idea of Industry 4.0. The BOST method takes into account the intangible resources of enterprises such as customer well-being, product innovation, cooperation with cooperators, the self-reliance responsibility of employees, the development of technology, and the nurturing of the enterprise culture. This BOST survey is described in more detail in the work of [51]. In addition, in order to ensure a broader scope of analysis, the survey includes such factors as trust in relations with employees, the size of the market offer, the quality of the goods sold, the price of the goods offered, own research and development work, the purchase of research and development work, as well as factors relating directly to the idea of Industry 4.0: automation, advanced digital technologies, capital (understood in material terms, i.e., machinery and equipment), entrepreneurship, and the combination of physical and virtual spheres of production. The procedure of taking into account a larger number of factors makes it possible to carry out a multi-faceted analysis of the foundry pre-casting companies.

After conducting a survey using the BOST survey, a face-to-face interview should be conducted with employees. The interview should be carried out in the form of a dialogue that allows the researcher to obtain information from the respondent that will be useful in the context of achieving the set research objective. With regard to the presented model, the subject of the interviews should concern the technological level and market position of the company. The face-to-face interview was found to be the best within the discussed sequence of methodological steps because during the meeting, it is possible to better clarify questions that were not understood. In addition, this solution provides a better understanding of the answers and allows us to establish a deeper connection with our interviewee.

Step 3—Statistical analysis of the obtained results

As part of the graphical representation of the obtained results, it is necessary to create a numerical characterization of the data, i.e., assessments of the importance of the factors that describe the 3 × 3 matrix (technological capabilities and market position). In order to have a good understanding of the obtained assessments, initially, the result is presented using a lollipop chart. Then, on the substrate of the modified 3 × 3 matrix, one should place the individual pairs of results in the corresponding poms of the matrix, showing their distribution. Modification of the 3 × 3 matrix refers to the indication of the correlation between technological capabilities (the X axis) and market position (the Y axis) (in the original version, the Y axis indicates the competitiveness of the product). Figure 2 shows the characteristics of the modified 3 × 3 matrix with the designations of the nine strategies. Interventionary studies involving animals or humans, as well as other studies that require ethical approval, must list the authority that provided approval and the corresponding ethical approval code.

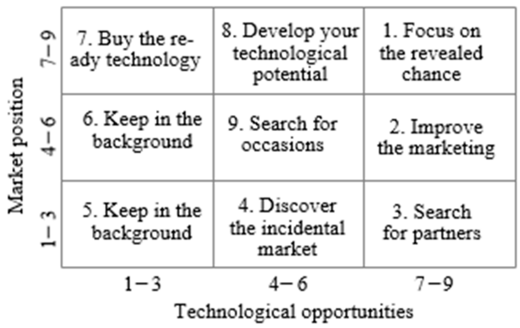

Figure 2. Characteristics of the 3 × 3 matrix in the modified version with the designation of its zones (management strategies).

The 3 × 3 matrix, in its original version, was used in the study [55], while its modifications were applied in [56–58]. Within the matrix, 9 areas indicative of the technological position of the analyzed production facility are separated. Each area of the 3 × 3 matrix proposes a specific development strategy that must be undertaken to achieve success. It is desirable to achieve field 1—"Focus on the revealed chance". This box indicates that all of the pairs of characteristics located there received scores in the range of 7–9. In the modified version, box 1, in addition to recommending a strategy, also indicates the pairs of factors that are among the most important (scores in the range of 7–9) and to which the most attention should be paid when improving production processes and creating development strategies in the context of the implications of Industry 4.0 in the enterprise and achieving market success.

The use of the 3 × 3 matrix in the technology data analysis model is predicated on the significant number of benefits it provides. The matrix is intuitive and user-friendly in nature. Each area in the matrix pre-presents a clearly defined approach to enterprise development, making it easy to interpret and apply. The biaxial approach of the 3 × 3 matrix provides an equalized assessment. In addition to its primary use, i.e., diagnosis of the enterprise's position, the matrix can serve as a strategic tool for planning and predicting development paths. Such predictability allows us to proactively plan transitions between areas of the matrix by implementing the appropriate strategies indicated therein. The use of the 3 × 3 matrix in the framework of the stage under discussion is the most appropriate solution because it provides predictability of the development direction of the enterprise, which allows for the proactive planning of transitions between areas of the matrix by implementing the relevant strategies indicated therein.

The next step refers to the identification of dominant points (dominant pairs of results regarding technological capabilities and market position) within each of the 9 areas of the 3 × 3 matrix. The purpose of this step is to perform analyses of the zones of the 3 × 3 matrix as separate metric spaces. The dominant points are considered to be the numbers with the highest value. The dominant points are the centers of circles and rings with radii of 1–4. A radius value of 1 indicates the center of a specific area of the matrix.

The last step of the method concerns the analysis of the coefficient of variation, which is the quotient of the non-relative measure of variation and the corresponding mean. This coefficient indicates the ratio of the standard deviation to the mean value. It is classified as a measure of dispersion and helps determine the degree of variation in the value of a variable. The coefficient of variation is mainly useful in situations where comparisons are made between the variability of traits in two populations and when the researcher makes analyses from the range of variation between different measures [59,60]. The feature under study is the percentage of survey results placed within the resulting rings. In the classical approach, i.e., statistical analysis of survey and interview results, the study is concerned with analyzing the level of variation in the distribution of factor importance ratings within the matrix.

4. Model Verification and Results

The integration and thus model checking of the data analysis in the metric space was performed at one of the production companies in the foundry industry, which is located in the southeastern part of Poland.

The foundry industry, which is popular in Poland, especially in the southeastern part of the country, is one of the heavy industries with a significant negative impact on the environment. As part of the implementation of the idea of sustainable development, and under pressure from the European Union, this industry is being forced to undertake radical modernization. These changes must be implemented according to the adopted strategies. This activity can be helped by this study. Using modern developments as well as proven and integrated methodologies, it is possible to assist managers of foundry companies and beyond in adapting their companies to the requirements of modern Industry 4.0.

Stage 1—preparation of the study

As part of the test of the developed analysis model, the manufacturing process of an intake manifold used in automotive applications was considered as the subject of the study. The task of the manifold is to supply the fuel–air mixture or the air itself to the engine cylinders with the lowest possible flow resistance. The product created by the selected production process is one of the mainly produced products (in terms of number) in the company.

A panel of experts was selected from among the company's management staff, which included a quality control manager, a product marketing manager, and a technology department manager. The selection of the composition of the team of research experts took into account the predisposition of employees to meet the requirements of analyzing data on the technology used and the market situation, including the company's position in the market in the context of the idea of Industry 4.0.

The purpose of the implications of the developed model is to analyze the data of the current state of the production process of intake manifolds used in automotive applications and the market position. Thanks to the in-depth analysis of the factors affecting the process under study, it is possible to eliminate the sensitive factors affecting disruptions during innovation, which will effectively ensure an increase in technological capabilities and a high level of competitiveness of the product.

Stage 2—Diagnostic survey

Employees of managers and executives of the production department, technology department, quality control department, and product marketing department were selected for the survey. A total of 28 people participated in the survey. This group of employees is responsible for controlling and improving the extrusion process and the product, i.e., the suction manifold. The survey was conducted in the fourth quarter of 2023. The indicated number of respondents is due to the fact that the research carried out in the study is a pilot study. The survey was mandatory, and the return rate was 100%. The survey questions were subject to validation. The enterprise employs about 1300 people.

Selected managerial and executive employees, thinking about the company where they work, were asked to answer the following question: what factors determine the development concept of your company? They were to rate the various factors of innovation on a scale of 1–9 (where 1—the least important factor; 9—the most important factor). Factors mentioned in the question in the context of technological capabilities are product innovation, independence of employees, responsibility of employees, development of technology, automation, advanced digital technologies, capital (understood in material terms, i.e., machinery and equipment), entrepreneurship, and the combination of physical and virtual spheres of production. Factors relating to market position are customer interest, cooperation with partners, trust in relations with employees, preservation of culture in the company, size of the market offer, quality of goods sold, price of goods offered, own research and development work, purchase of research, and development work.

Following the survey, face-to-face interviews were conducted with management staff to expand the knowledge gathered. The interviews covered their views on the competitiveness of the product and the company's market position. The issue of the ability to plan, create, and sell the product was raised, as well as operational competitiveness (capturing the technical skills that facilitate the functioning of the enterprise in a given market) and system competitiveness (testifying to the wide range of activities of the enterprise leading to the improvement and modernization of the implementation of the organization's processes in terms of Industry 4.0).

Stage 3—Statistical analysis of the obtained results

Based on the information obtained from the implementation of Stage 2, a numerical specification of the importance level ratings of the various factors indicating technological capabilities and market position was developed. The specification is shown in Figure 3.

Figure 3. Describing the level of importance of assessments of factors indicating technological capabilities (TP) and market position (MP), taking into account the areas of the 3 × 3 matrix (horizontal axis digits).

The lollipop chart shows the structure of evaluations of the two factors (technological capabilities—TP; market position—MP) awarded by employees, divided into 9 areas of a 3 × 3 matrix. In Figure 3, the numbers indicated on the vertical axis correspond to the areas of a 3 × 3 matrix.

In the next step, a map of the numbers of indications and evaluations of the analyzed factors—technological capabilities (TP) and market position (MP) acquired in stage 2 of the analysis—was developed (Figure 4).

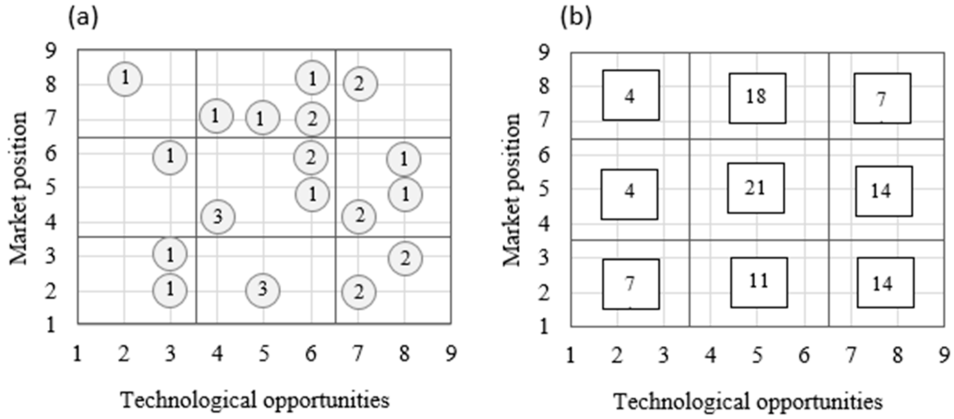

Figure 4. Analysis of the importance level assessments of pairs of factors indicating technological capabilities (TP) and market position (MP): (**a**) the unitary capture of pairs of factors; (**b**) factor structure in percentage terms.

The highest concentration of pairs of ratings is found in the middle part of the matrix. This fact indicates that the largest number of respondents gave grades 4–7 for the technological capabilities factor and grades 2–8 for the market position factor. With reference to part (b) of Figure 4, i.e., the percentage share of evaluation results, it can be seen that 21% of the evaluation pairs are located in part 9 (strategy: search for occasions) and 18% of the evaluation pairs in part 8 (strategy: develop your technological potential). Therefore, a practical recommendation is to intensify the company's activities in the area of the more efficient use of technological resources. The company should also increase its activity in shaping product competitiveness (making the product more attractive) and increasing its market position. Motivation to take the indicated actions in the analyzed area can be increased access to resources not previously owned, better use of the emerging opportunities of the environment, increased flexibility of activities, and increased positive image of the enterprise. Among respondents, 14% of employees believe that marketing activities should be improved, and new partners should be sought. Undertaking the indicated activities will move the results towards the desired field—field number 1.

Examining the distribution and structure of the results of the diagnostic survey within the 3×3 matrix, one can see the points with the highest value (dominant results). In each of the nine zones, the dominant points will be the centers of established circles with radii increasing sequentially by the value of 1. In the case where there is no dominant point in a zone, the center of the ring is taken as the point closest to zone 9 and the score of 9 points in both the x and y axes of the 3×3 matrix. The centers (midpoints) of the rings have a radius value of 1. Within the zones of the 3×3 matrix, the following points were considered as the centers of the rings: area "1" point with coordinates: (7;8); area "2" point with coordinates: (7;4); area "3" point with coordinates: (8;3); area "4" point with coordinates: (5;2); area "5" point with coordinates: (3;3); area "6" point with coordinates: (3;6); area "7" point with coordinates: (2;8); area "8" point with coordinates: (6;7); and area "9" point with coordinates: (6;6). In this way, it is possible to analyze assessment structures in metric space.

As part of further analyses, metric spaces were created in the form of rings appropriately superimposed on individual areas of a 3×3 matrix (Figure 5).

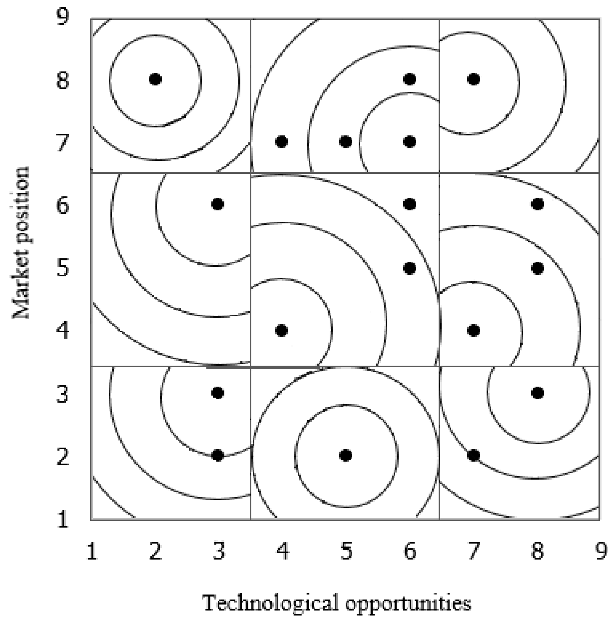

Figure 5. Positioning of rings against 3 × 3 matrix zones.

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

Table 2. Layout of the structure of a set of rings against the background of the metric space.

Ring Structure		3 × 3 Matrix Zone								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Location of rings within the zones of the 3 × 3 matrix	$0 \leq r < 1$	100	50	50	100	50	100	100	40	50
	$1 \leq r < 2$	0	25	50	0	50	0	0	40	0
	$2 \leq r < 3$	0	25	0	0	0	0	0	20	17
	$3 \leq r < 4$	0	0	0	0	0	0	0	0	33

One of the statistical measures of analysis is the coefficient of variation. This coefficient is a type of measure that describes the relationship that occurs between the analyzed distributions that differ both from each other and from the values of the characteristics around the central values. The basis for the analysis of the coefficient of variation of the percentage of the factors presented is a 3 × 3 matrix indicating the significance ratings of pairs of factors (technological capabilities, market position) in the form of points of a specific position. The values of coefficients of variation and the number of non-zero rings within the zones of the 3 × 3 matrix are indicated in Table 3.

Table 3. List of coefficients of variation of percentages of factor pairs within rings.

3 × 3 Matrix Zone	Coefficient of Variation of Percentages of Factor Pairs	Number of Non-Empty Rings
1	0	1
2	35	3
3	0	2
4	0	1
5	0	2
6	0	1
7	0	1
8	28	3
9	40	3

When interpreting the values of the coefficient of variation, it should be remembered that the smaller the coefficient of variation, the better. Within the considered zones of the 3×3 matrix, the values of the coefficient of variation of the percentage of points in the outlined rings are in the range of 0–40 (Table 3). The achieved values of the coefficient of variation indicate that six zones (zone 1 and 3–7) are homogeneous; they show no variability. In contrast, the remaining zones (zone 2, 8, and 9) are characterized by average variability.

Based on the data obtained (Table 3), it is possible to create a ranking of the separated zones of the 3×3 matrix using the topological matrix and the rings created. The zones were hierarchized on the basis of the value of the coefficient of variation of the importance ratings of the analyzed factors (technological capabilities and market position) placed in the 3×3 matrix. The developed series looks as follows:

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

The ranking was determined according to the principle of interpreting the coefficient of variation; the less, the better—that is, starting with the smallest values. The brackets used in the series indicate the equal value of the coefficient of variation within the zones.

The result of the analysis shows the agreement of the respondents regarding the significant influence of the factors considered in the survey on the sphere of technological capability and market position. The obtained ranking of the level of variability in the area of zones of the 3×3 matrix indicates the level of importance of the factors influencing technological capabilities and market position. The key factors for the enterprise in the context of building competitiveness are the factors located in zone 9. Slightly less important are the factors from zone 2 and, in turn, from zone 8. The following pairs of factors were located within the aforementioned zones:

- Automation (a factor relating to technological capabilities) and quality of goods sold (a factor relating to market position)—zone 9.
- Application of advanced digital technologies (factor on technological capabilities) and own research and development (factor on market position)—zone 2.
- The development of technology (technological capabilities factor) and the price of goods offered (market position factor)—zone 8.

Among the factors with the greatest impact were those directly related to the concept of the fourth industrial revolution (automation, advanced digital technologies, and technology development). These factors are characterized by a significant impact on the competitiveness of the organization. The importance of the other analyzed factors from both the group of factors related to technological capabilities and market position was assessed at an equal (least significant) level, i.e., no variability was detected.

The obtained result indicates an unambiguous position in achieving the goal, maintaining a leading market position and achieving the desired field in the 3×3 matrix, which means embracing the strategy: "Search for occasions". For the analyzed company, a strategy is recommended within the framework in which the directions of development will concern the factories of groups 9, 2, and 8.

Metric spaces appear in many areas of mathematics such as mathematical analysis, order theory, and algebraic geometry. Metric space is a concept that is located on the borderline between mathematical analysis and topology. Thanks to this concept, we are able to define, in a natural way, many concepts known from mathematical analysis in a broader class of objects and conduct analyses within this space. Typically, these analyses do not apply to manufacturing engineering and process improvement. However, the proposed model of data analysis in the area of metric space makes it possible to identify the factors with the greatest impact on the technological capabilities and market position of the enterprise in the context of the implications of the idea of Industry 4.0. In addition, the verification of the developed model of technological data analysis highlighted that sensibly conducted data analysis in metric space using complementary methods and techniques has a significant positive impact on ensuring the continuity of adequate development directions of the enterprise.

The proposed method makes it possible to conduct analyses to support the management of technological and organizational space in manufacturing enterprises. The use of the model makes it possible to identify the key factors of development of a specific enterprise that testify to the technological capabilities, market position, and potential with respect to the implications of Industry 4.0. Thus, it will be possible to adopt adequate directions of development in the internal and external space. The proposed model for analyzing technological data is characterized by a broad application dimension.

The proposed model can be used by manufacturing companies. Each of them selects specific experts (respondents). The conclusions of the developed method will be dedicated to this specific enterprise. The development strategy established according to the methodology is not necessarily the right strategy for another enterprise with similar characteristics.

5. Conclusions

The optimal level of efficiency in the sphere of management of a manufacturing enterprise under certain internal and external conditions allows the organization to maintain high competitiveness, which determines its long-term development. The research carried out was aimed at developing an innovative model of data analysis within the metric space, allowing us to identify the factors with the greatest impact on the technological capabilities and market position of the enterprise against the backdrop of the idea of Industry 4.0. The methodology used a 3×3 matrix within which the results of the surveys were located, and statistical analyses were performed in order to propose a new use of scientific information and the implementation of in-depth analysis to support the management of the technological and organizational space. The proposed analysis model is characterized by a wide application dimension.

Adopting the topological metric to analyze the data contained in the 3×3 matrix by dividing its zones into rings, it is possible to calculate the value of the coefficient of variation within the standardized zones. This procedure makes it possible to create a ranking based on the values of the coefficients of variation of the importance ratings of the analyzed factors of the separated zones. The ranking indicates the level of agreement of respondents on the determination of the impact of individual factors on the technological capabilities and market position of the enterprise. In addition, verification of the developed data analysis model highlighted that judiciously conducted data analysis has a significant positive impact on ensuring the continuity of adequate development directions of the enterprise in both internal and external space. The resulting series of assessments of the importance of factors influencing technological capabilities and market position indicate the positive importance of automation and technical development in the manufacturing process. Factors directly related to the idea of Industry 4.0 (product innovation, technology development) were found to be the factors with the greatest impact on the competitiveness of the enterprise, which is influenced by the use of technological capabilities. In the evaluation of this group of factors, the lowest level of variation in the variation index parameter was identified. This shows that respondents clearly emphasize the importance of such activities in order to maintain a leading market position and move closer to the desired field in the 3×3 matrix, indicating “Search for occasions” strategies. This conclusion is in line with the paradigms of the fourth industrial revolution.

Future research directions will include the implication of the developed model of data analysis in the metric space to other manufacturing processes in the framework in which the leading products of the enterprise are produced in order to ensure the identification of the appropriate direction of improvement activities in the use of technological opportunities and to ensure market position. The actions taken contribute to technological development and increase the level of competitiveness of the studied enterprise. The next step in the development of the method will be to increase the number of analyzed factors relating to the sustainable development and management of the production enterprise. The presented course of research implementation can support decision-making in the field of the management and development of production enterprises.

Author Contributions: Conceptualization, K.C. and A.P.; methodology, K.C. and A.P.; validation, K.C.; formal analysis, A.P.; data curation, K.C.; writing—original draft preparation, K.C. and A.P.; writing—review and editing, K.C. and A.P.; visualization, K.C. and A.P.; supervision, K.C. and A.P.; project administration, A.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Baryshnikova, N.; Kiriliuk, O.; Klimecka-Tatar, D. Enterprises' strategies transformation in the real sector of the economy in the context of the COVID-19 pandemic. *Prod. Eng. Arch.* **2021**, *1*, 8–15. [CrossRef]
2. Furman, J.; Malysa, T. The role of visual management in the organization of safe work in production companies. *Prod. Eng. Arch.* **2023**, *29*, 195–200. [CrossRef]
3. Klimas, P.; Czakon, W.; Fredrich, V. Strategy frames in coopetition: An examination of coopetition entry factors in high-tech firms. *Eur. Manag. J.* **2022**, *40*, 258–272. [CrossRef]
4. Ligarski, M.J. Methodology of problem analysis in the quality management system with the use of systems approach. *Manag. Syst. Prod. Eng.* **2018**, *26*, 157–161. [CrossRef]
5. Klimecka Tatar, D.; Niciejewska, M. Small-sized enterprises management in the aspect of organizational culture. *Rev. Gest. Tecnol.—J. Manag. Technol.* **2021**, *21*, 4–24. [CrossRef]
6. Antonelli, C.; Crespi, F.; Scellato, G. Internal and external factors in innovation persistence. *Econ. Innov. New Technol.* **2013**, *22*, 256–280. [CrossRef]
7. Pacana, A.; Czerwińska, K. Analysis of the causes of control panel inconsistencies in the gravitational casting process by means of quality management instruments. *Prod. Eng. Arch.* **2019**, *25*, 12–16. [CrossRef]
8. Tikhonor, A.; Zelentsova, L. Analysis of External and Internal Factors of Business Competitiveness. *Qual.-Access Success* **2021**, *22*, 16–19.
9. Bilomistniy, O.; Bilomistna, I.; Galushko, Y. Influence external and internal factors to financial security of enterprise. *Financ. Credit. Act.—Probl. Theory Pract.* **2017**, *1*, 105–111. [CrossRef]
10. Nasim, K. Role of internal and external organizational factors in TQM implementation: A systematic literature review and theoretical framework. *Int. J. Qual. Reliab. Manag.* **2018**, *35*, 1014–1033. [CrossRef]
11. Pacana, A.; Czerwińska, K. Comparative tests of the quality of the piston combustion chamber for a diesel engine. *Teh. Vjesn.—Tech. Gaz.* **2020**, *27*, 1021–2024. [CrossRef]
12. Gawlik, R. Methodological aspects of qualitative-quantitative analysis of decision-making processes. *Manag. Prod. Eng. Rev.* **2016**, *7*, 3–11. [CrossRef]
13. Pietraszek, J.; Radek, N.; Goroshko, A.V. Challenges for the DOE methodology related to the introduction of Industry 4.0. *Prod. Eng. Arch.* **2021**, *26*, 190–194. [CrossRef]
14. Pacana, A.; Czerwińska, K. Model of Diagnosing and Searching for Incompatibilities in Aluminium Castings. *Materials* **2021**, *14*, 6497. [CrossRef] [PubMed]
15. De Valon, T.; Cegarra-Navarro, J.G.; Garcia-Perez, A.; Martinez-Martinez, A. Co-creating sustainable competitiveness in an unpredictable business reality. *Proc. Int. Conf. Bus. Excell.* **2022**, *16*, 47–58. [CrossRef]
16. Wolniak, R. The assessment of significance of benefits gained from the improvement of quality management systems in Polish organizations. *Qual. Quant.* **2013**, *47*, 515–528. [CrossRef]
17. Borowiecki, R.; Olesiński, Z.; Rzepka, A.; Hys, K. Development of teal organisations in economy 4.0: An empirical research. *Eur. Res. Stud. J.* **2021**, *24*, 117–129. [CrossRef]
18. Ritter, T.; Pedersen, C.L. Digitization capability and the digitalization of business models in business-to-business firms: Past, present, and future. *Ind. Mark. Manag.* **2020**, *86*, 180–190. [CrossRef]
19. Csiki, O.; Demeter, K.; Losonci, D. How to improve firm performance?—The role of production capabilities and routines. *Int. J. Oper. Prod. Manag.* **2023**, *43*, 1–26. [CrossRef]
20. Liu, Y.; Wang, X.; Yang, Y.D. The impact of strategic knowledge disclosure on enterprise innovation performance. *Manag. Decis. Econ.* **2023**, *44*, 2582–2592. [CrossRef]
21. Luo, Y.D.; Zahira, S.A. Industry 4.0 in international business research. *J. Int. Bus. Stud.* **2023**, *54*, 403–417. [CrossRef]
22. Pech, M.; Vanecek, D. Barriers of new technology introduction and disadvantages of industry 4.0 for industrial enterprises. *Serbian J. Manag.* **2022**, *17*, 197–206. [CrossRef]

23. Ghobakhloo, M.; Vilkas, M.; Stefanini, A.; Grybauskas, A.; Marcinkevicius, G.; Petraite, M.; Sarvari, P.A. Developing capabilities underlying to Industry 4.0 design principles within the manufacturing context. *J. Manuf. Technol. Manag.* **2023**, *34*, 1183–1207. [CrossRef]
24. Alsaadi, N. Modeling and Analysis of Industry 4.0 Adoption Challenges in the Manufacturing Industry. *Processes* **2022**, *10*, 2150. [CrossRef]
25. Salunkhe, O.; Berglund, A.F. Industry 4.0 enabling technologies for increasing operational flexibility in final assembly. *Int. J. Ind. Eng. Manag.* **2022**, *13*, 38–48. [CrossRef]
26. Rosario At Dias, J.C. Industry 4.0 and Marketing: Towards an Integrated Future Research Agenda. *J. Sens. Actuator Netw.* **2022**, *11*, 30. [CrossRef]
27. Ulewicz, R.; Czerwińska, K.; Pacana, A. A rank model of casting non-conformity detection methods in the context of Industry 4.0. *Materials* **2023**, *16*, 723. [CrossRef] [PubMed]
28. Jamwal, A.; Agrawal r Sharma, M.; Giallanza, A. Industry 4.0 Technologies for Manufacturing Sustainability: A Systematic Review and Future Research Directions. *Appl. Sci.* **2021**, *11*, 5725. [CrossRef]
29. Campos, T.L.R.; Nunhes, T.V.; Harney, B.; de Oliveira, O.J. Corporate sustainability in entrepreneurial settings: Green management and operational fairness as joint drivers of venture competitiveness. *J. Small Bus. Enterp. Dev.* **2023**, *30*, 342–368. [CrossRef]
30. Miskiewicz, R.; Wolniak, R. Practical application of the industry 4.0 concept in a steel company. *Sustainability* **2020**, *12*, 5776. [CrossRef]
31. Hong, P.; Jagani, S.; Pham, P.; Jung, E. Globalization orientation, business practices and performance outcomes: An empirical investigation of B2B manufacturing firms. *J. Bus. Ind. Mark.* **2023**, *38*, 2259–2274. [CrossRef]
32. Shi, L.; Gao, S.; Xu, A.R.; Zheng, K.X.; Ji, Y.P.; Dong, X.L.; Xing, L.Z. Influence of Enterprise's Factor Inputs and Co-Opetition Relationships to Its Innovation Output. *Sustainability* **2023**, *15*, 838. [CrossRef]
33. Brilinger, A.S.; Els, C.; Schafer, B.; Bender, B. Business model risk and uncertainty factors: Toward building and maintaining profitable and sustainable business models. *Bus. Horiz.* **2020**, *63*, 121–130. [CrossRef]
34. Ginevicius, R.; Gedvilaite, D.; Stasiukynas, A.; Suhajda, K. Complex Expert Assessment of the State of Business Enterprises. *Acta Polytech. Hung.* **2020**, *19*, 135–150. [CrossRef]
35. Datsenko, G.; Kotseruba, N.; Krupelnytska, I.; Kudyrko, O.; Lobacheva, I.; Otkalenko, O. Analytical Toolkit in Terms of Increasing Competitiveness Under Unstable Economic Conditions. *Financ. Credit. Act.—Probl. Theory Pract.* **2022**, *3*, 216–223. [CrossRef]
36. Hrosul, V.; Zubkov, S.; Mkrtchyan, T. The Development Core of Enterprise: Theoretical Aspect. *Balt. J. Econ. Stud.* **2021**, *7*, 73–81. [CrossRef]
37. Li, Z.G.; Lou, W.F.; Li, Y.S. Evaluation of Advantageous Resources in Enterprise Based on Rough Set Theory. In *Comprehensive Evaluation of Economy and Society with Statistical Science*; Aussino Academic Publishing House: Sydney, Australia, 2010; pp. 153–157.
38. Schaefer, J.L.; Tardio, P.R.; Barierle, I.C.; Nara, E.O.B. GIANN-A Methodology for Optimizing Competitiveness Performance Assessment Models for Small and Medium-Sized Enterprises. *Adm. Sci.* **2023**, *13*, 56. [CrossRef]
39. Ejaz, M.R. Smart Manufacturing as a Management Strategy to Achieve Sustainable Competitiveness. *J. Knowl. Econ.* **2023**. [CrossRef]
40. Parast, M.M.; Safari, A. Enhancing the quality and competitiveness of small businesses: A pooled cross-sectional analysis. *Int. J. Prod. Econ.* **2022**, *246*, 108410. [CrossRef]
41. Anawade, P.A.; Sharma, D.S. The Influence of Marketing Strategy on Business Results: An Empirical Study for Selected Small and Medium Enterprises (SMEs) of Nashik Municipal Corporation (NMC). *Int. J. Early Child. Spec. Educ.* **2022**, *14*, 5764–5769. [CrossRef]
42. Rajesh, R. An introduction to grey influence analysis (GINA): Applications to causal modelling in marketing and supply chain research. *Expert Syst. Appl.* **2022**, *212*, 118816. [CrossRef]
43. Lin, S.; Xu, S.Y.; Liu, Y.; Zhang, L.Y. Destination brand experience, brand positioning, and intention to visit: A multi-destination comparison study. *J. Vacat. Mark.* **2023**. [CrossRef]
44. Matthe, M.; Ringel, D.M.; Skiera, B. Mapping Market Structure Evolution. *Mark. Sci.* **2022**, *42*, 589–613. [CrossRef]
45. Fluhrer, P.; Brahm, T. Positioning in SMEs: Entrepreneurs' perceptions and strategies. *J. Res. Mark. Entrep.* **2023**, *25*, 431–454. [CrossRef]
46. Hong, R.Y.; Zhang, Z.; Zhang, C.; Hu, Z.H. Is brand globalness compatible with brand country-of-origin? An investigation of hybrid brand positioning strategies for emerging market brands. *Int. Mark. Rev.* **2022**, *40*, 49–79. [CrossRef]
47. Nelke, M. *Strategic Business Development for Information Centres and Libraries*; Chandos Information Professional Series; Chandos Publishing: Witney, UK, 2010; pp. 89–103.
48. Jung, K.; Morris, K.C.; Lyons, K.W.; Leong, S.; Cho, H. Mapping Strategic Goals and Operational Performance Metrics for Smart Manufacturing Systems. *Procedia Comput. Sci.* **2015**, *44*, 184–193. [CrossRef]
49. Delzenne, N.; Deuts Ne Lobo, D.N.; Grimble, G. Presentation and publication skills: How to develop a protocol and write a grant. *Clin. Nutr.* **2023**, *57*, 73–76. [CrossRef] [PubMed]
50. Schimpf, C.; Castellani, B. Approachable modeling and smart methods: A new methods field of study. *Int. J. Soc. Res. Methodol.* **2022**, *27*, 1–15. [CrossRef]
51. Borkowski, S. *Toyotaryzm, Wyniki Badań BOST*; Wydawnictwo, PTM: Warszawa, Poland, 2012.

52. Vanichchinchai, A. The effects of the Toyota Way on agile manufacturing: An empirical analysis. *J. Manuf. Technol. Manag.* **2022**, *33*, 1450–1472. [CrossRef]
53. Black, J.T. Design rules for implementing the Toyota Production System. *Int. J. Prod. Res.* **2007**, *45*, 3639–3664. [CrossRef]
54. Pacana, A.; Siwiec, D. Universal Model to Support the Quality Improvement of Industrial Products. *Materials* **2021**, *14*, 7872. [CrossRef] [PubMed]
55. Lowe, P. *Management of Technology: Perception and Opportunities*; Chapman & Hall: London, UK, 1995.
56. Borkowski, S.; Ingaldi, M.; Jagusiak-Kocik, M. The use of 3 × 3 matrix to evaluate a manufacturing technology of chosen metal company. *Manag. Syst. Prod. Eng.* **2014**, *15*, 121–125. [CrossRef]
57. Klimecka-Tatar, D.; Ingaldi, M. Assessment of the Technological Position of a Selected Enterprise in the Metallurgical Industry. *Mater. Res. Proc.* **2020**, *17*, 72–78. [CrossRef]
58. Ingaldi, M. Use of the SWOT ANALYSIS and 3 × 3 matrix to determine the technological posistion of the chosen metal company. *Acta Metall. Slovaca—Conf.* **2014**, *4*, 207–214. [CrossRef]
59. Altunkaynak, B.; Gamgam, H. Bootstrap confidence intervals for the coefficient of quartile variation. *Commun. Stat.-Simul. Comput.* **2019**, *48*, 2138–2146. [CrossRef]
60. Jalilibal, Z.; Amiri, A.; Castagliola, P.; Khoo, M.B.C. Monitoring the coefficient of variation: A literature review. *Comput. Ind. Eng.* **2021**, *161*, 107600. [CrossRef]