Journal of Open Innovation: Technology, Market, and Complexity

MDPI

Article

Systematic Assessment of Product Quality

Radoslaw Drozd [1] and Radoslaw Wolniak [2,*]

[1] Department of Informatics in Management, Faculty of Management and Economics, Gdansk University of Technology, Traugutta 79, 80-233 Gdansk, Poland; radoslaw.drozd@pg.edu.pl

[2] Department of Organization and Management, Institute of Economy and Informatics, Silesian University of Technology, Akademicka 2A, 44-100 Gliwice, Poland

* Correspondence: radek_wol@o2.pl

Abstract: The article describes an innovative metrizable idea for systemic assessments of product quality within the baking industry. Complex product quality analysis requires the employment of metrizability criteria for factors that impact the quality of the product, and these are called determinants. Therefore, such analysis is only possible with the use of systems engineering. A system represents the potential of a manufacturing process, of major impact on quality. Composites of the manufacturing process make up the determinants of bread quality, grouped into three sets: raw materials, manufacturing technology, and manufacturing organization and technique. This paper also contains methodological implications for the construction of algorithms for manufacturing process potential determinants. Metrizable product quality assessment is a very important issue in the context of its implementation in manufacturing companies. Its use allows for obtaining comprehensive data on the quality status of a product. It is an important tool for analyzing and forecasting modern quality trends. The method presented in the article is new, innovative, and practical; and its vector representation may prove useful in Quality 4.0. The method could be an important point of reference for managers, directors, and decision makers who must determine the best metrizability criteria for systemic product quality assessments, and could prove useful in Industry 4.0 in the bakery industry. The main value of the paper is the presentation of a new, extensive method for systemic assessments of product quality based on vector analysis in industrial organization. We trialed the method in the baking industry. We concluded that the method is a contribution to management science, especially in the field of quality management, because this approach is not used in business and is not described in relevant international literature.

Keywords: system; systems engineering; quality determinants; Industry 4.0

Citation: Drozd, R.; Wolniak, R. Systematic Assessment of Product Quality. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 235. https://doi.org/10.3390/joitmc7040235

Academic Editor: JinHyo Joseph Yun

Received: 10 August 2021
Accepted: 5 November 2021
Published: 2 December 2021

1. Introduction

The problems of contemporary industry lie in strict competition [1]. When competing for customers, fundamental strategic parameters are the quality and price of each product [2]. Those parameters are indispensable for customers' decisions. Customers generally tend to buy products which have appropriate prices and high enough quality for their demands [3].

Increased social demand for quality made it necessary to develop new systems of assessing quality [4,5]. Those systems should be developed to increase the possibility of systems giving customers the value they need. To do this, we need methods which can be used to measure the level of quality delivered to customer [6]. The literature treats quality [6,7] as metrizable to only a low degree. They think that there are many problems connected with the appropriate measurement of quality [8].

We think that quality management in any industry is only possible when we measure the level of quality. Thus, on the basis on this assumption, the authors of this paper attempted a systemic product quality assessment in the baking industry, by using a new approach based on systems engineering [9]. We think that the baking industry is an interesting topic because it is widespread in all countries of the word, which makes a study on it interesting for the international reader. Additionally, the intermediate stage of technological development of this industry gave us the possibility to analyze an industry with new technology, but also some outdated technology [10].

To give a good quality product to a customer, an organization needs to have an appropriate production system. Therefore, we thought to use the systems approach to quality management. A system is a universal primary model. The art of constructing systems is called systems engineering [11]. A system entails the existence of a functional whole, composed of a number of elements that are in mutual relations, and which are needed for the whole to serve its function [12,13].

To implement a systems approach in manufacturing, we need to define all elements influencing a system's functioning. In manufacturing, practically all the elements (determinants) which impact quality are associated with the manufacturing process and are mutually dependent functionally [14,15]. Therefore, the role of the system in this paper is served by the manufacturing process [16,17].

According to the authors Chia-Nan Wang, Thanh Tuan Dang, and Ngoc Ai Thy Nguyen [18,19], the modern production process is the integration of intelligent, networked, autonomous digital and physical technologies (such as the Internet of Things, robotics, autonomous vehicles, and 3D printing) in the era known as Industry 4.0, which means there are opportunities for innovation, the development of production lines, and above all, the creation of intelligent factories.

In several studies, vector-based analyses has been used to resolve many problems related to the technical sciences. For example, one can find methods based on vector analysis in acoustics [20], building planning [21], and other technical topics [22]. However, during research using a large international database, we did not find any usage of vector analysis in the industrial management field. We used this mathematical concept to prepare a new method for systematic assessments of product quality. This method should be an interesting contribution to the field because of its novelty and possible practical implications.

The main disadvantages of the previously used methods of quality assessment are related to scalability, and because of that, they cannot achieve sufficient reliability and be involved in complex data analysis. Some methods used for services were based on self-assessment [23–25]. They can be used to check product quality in industrial environments. Some industrial enterprises use methods based on quality indexes [25–30]. Those methods are useful, but the use of vector analysis can allow a more complex approach with the possibility of multidimensional analysis of the quality-related problems.

Therefore, our goal for this paper was to present a new systemic product quality assessment method to be applied mostly in manufacturing businesses. We tested the method in the baking industry. The baking industry describes businesses that offer bread and associated products.

We had the following hypothesis:

Hypothesis 1 (H1). *It is possible to use vector analysis to assess the quality of products in a systemic way in the baking industry.*

To realize the goal of the paper, we needed to identify and analyze factors influencing products and their quality in the bakery industry. Factors that influence product quality vary across industries and sometimes even across product types [29,30]. The largest variations are seen among product groups in the food industry and in industrial production [31,32]. The authors chose the baking industry to define determinants of product quality [33,34]. Bread is a product consumed by many customers daily, and therefore, it requires special interest [35,36].

Regarding producing good quality bread, we should know that every manufacturing process is affected by material and financial elements. Raw materials and manufacturing technology [37–39], together with organization and techniques of manufacturing [40,41], influence the quality of the product directly. Taking into account this setup, we present the influences of the individual factors on bread quality. This subject's literature is limited. Studies mainly focused on entry material determinants.

Within the entry material group, quality determinants are related to [42–44]:

(1) Quality of the entry materials;
(2) Composition of materials (recipe);
(3) Proper definition of efficiency norms.

Additionally, a very important factor influencing bread quality is the technology each particular organization uses. Manufacturing technology has a positive influence on product quality [45,46] as long as the following criteria are satisfied: proper parameters are selected for the process; the adopted manufacturing processes are stable; and there is control over process efficiency [47–49]. The organizational and technical factors are related to the qualifications of staff and their involvement, the functionality and reliability of manufacturing equipment, technical progress, sanitary and hygienic conditions, and shipping and storage conditions [50–52].

The potential of the manufacturing process to improve bread quality may find its metrizable representation in two forms: scalar and vector. Scalar measures of the potential of the manufacturing process ought to be calculated with the use of statistical algorithms and be based on well-developed areas of social and economic life [34,53]. Vector measures are less known and require implementing algorithms that take into account weights, i.e., the impacts of the individual factors on the final quality of the product [54]. Such tasks are the domain of new challenges of analysis and prognosis for modern quality trends [8,33].

Our idea for measuring manufacturing process potential, in the context of improving bread quality, is presented as a state vector, whose three components are: entry materials, manufacturing technology, and manufacturing organization and technique. Each of the three vectors bears a different weight and content module, all of which are non-dimensional.

Very important to measuring bread production processes and bread quality is the systemic approach. The systemic approach is needed for the description of a manufacturing process in order to improve the quality of the final product. Thus, our solution should be useful in any manufacturing business. However, it needs to be taken into account that the quality determinants ought to be defined on a branch-by-branch or product-by-product basis.

2. Materials and Methods

Systemic Structure of a Manufacturing Process in the Baking Industry

The basic component of many people's diets is bread. Bread plays an invaluable role in regulating the work of the human digestive tract and constitutes a significant source of the body's daily energy requirements (approximately 25–30%). Bread was, is, and will probably remain a product of primary importance in terms of nutrition.

The increase in social requirements regarding the quality of bread made it necessary to introduce new system of solutions in which quality becomes a strategic goal. The concept of quality is a term that is difficult to define unequivocally due to its subjectivity. Customer requirements determine the level of product quality; hence quality is also a multidimensional and interdisciplinary concept.

Due to the authors' interest in the issues of bread quality, the most important articles and websites related to the topic (micro and small enterprises in the bakery industry) were analyzed.

Micro and small businesses in the bakery industry are crucial to the economic development of Europe. They constitute over 80% of all functioning bakeries in Europe. They are essential for the sustainable functioning of the economy and contribute to accelerating economic growth.

According to the authors' assessment, the Fourth Industrial Revolution and the increased pressures of competition in the bakery industry market mean that an important element influencing the improvement of the quality of products manufactured in the bakery industry is the formulation of new rules for the measurability (metrizability) of factors that will affect the quality of the products, one of which is presented in this article.

The systemic structure of a manufacturing process is part of the structure of an enterprise. Figure 1 shows a systemic structure of a bread manufacturing process with the use of a model approach founded on system engineering.

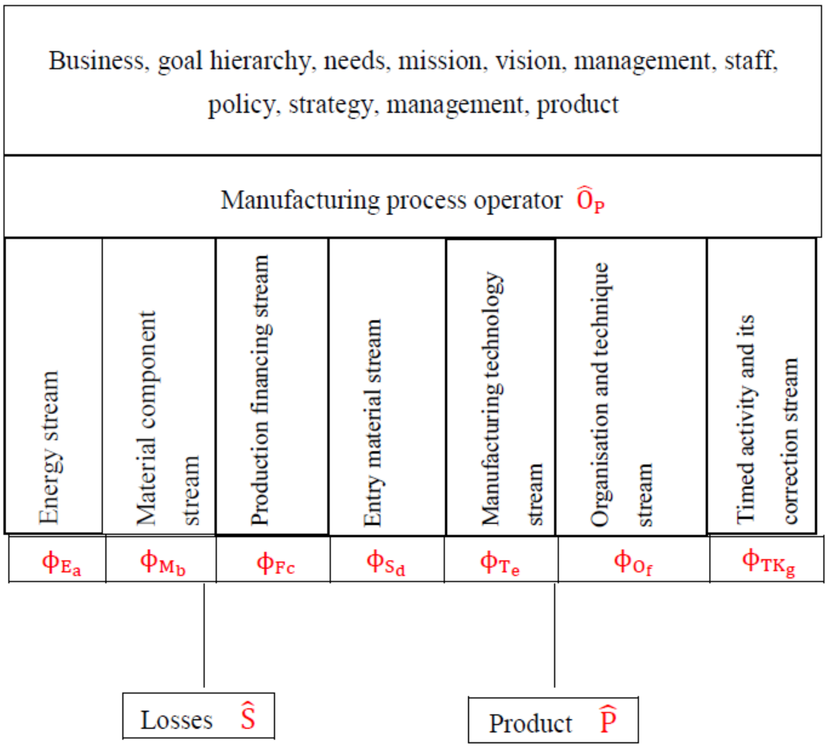

Figure 1. Systemic structure of a bread manufacturing process.

The operator manufacturing process activity space $\hat{O}_P$ in the bakery is powered by seven streams. The operator is identified with the manufacturing of the associated product $\hat{P}$. The activity of the operator $\hat{O}_P$ in the input streams also causes inevitable losses $\hat{S}$.

The input material of the system is composed of the energy stream ϕ_{E_a}, material element stream ϕ_{M_b}, manufacturing finance stream ϕ_{Fc}, material stream ϕ_{S_d}, manufacturing technology stream ϕ_{T_e}, organization and technique stream ϕ_{O_f}, and timed activity and correction stream ϕ_{TK_g}.

Each of the above streams represents the number of relevant actions in time.

The types of activity of individual streams define the goal of the activity of the whole system, i.e., product quality assessment. Streams are closely linked with the final product. The number and types of input streams may change depending on the industry branch under analysis.

The above leads to the conclusion that the representation of the potential of a product is an integral part of a manufacturing system, and it should bear all the characteristics of the system, understood as permanent activity in time and space.

3. Results

3.1. Components of the Manufacturing Potential

The description of the activity of the operator $\hat{O}_P$ within the system presented in Table 1 is of fundamental importance to product quality assessments. The description can be delivered in three ways: heuristic, scalar, or vector [31,51].

Table 1. Product (bread) components. Source: own elaboration.

Potential of the Manufacturing Process $\overrightarrow{P_p}$		
Entry Materials $\overrightarrow{S}$	**Manufacturing Technology $\overrightarrow{T}$**	**Manufacturing Organisation and Technique $\overrightarrow{O}$**
Quality of the production raw materials $\overrightarrow{S_1}$	Selection of optimal process parameters $\overrightarrow{T_1}$	Staff qualification and involvement $\overrightarrow{O_1}$
Material composition $\overrightarrow{S_2}$	Stability of the assumed manufacturing processes $\overrightarrow{T_2}$	Functionality and reliability of machinery $\overrightarrow{O_2}$
Proper setting of efficiency norms $\overrightarrow{S_3}$	Process efficiency control, including:	Technological progres $\overrightarrow{O_3}$
	- that of individual process phases $\overrightarrow{T_3}$	Hygiene and sanitary conditions $\overrightarrow{O_4}$
	- that of interoperational semi-finished product quality $\overrightarrow{T_4}$	Storage and shipment conditions $\overrightarrow{O_5}$

This paper suggests the rules for scalar and vector descriptions. The vector description of the activity of the operator $\hat{O}_P$ is, in this case, optimal because of it taking into account the weighs of the individual factor groups that influence the final product's quality in the manufacturing system. Therefore, the representation of the activity of the vector $\hat{O}_P$ will be the vector $\overrightarrow{O_p}$ within a rectangular coordinate grid of weight (x), and the content module (y) takes non-dimensional values.

Table 1 presents the list of factors that influence the form of the vector $\overrightarrow{P_p}$. It encompasses three groups of activity of the operator $\hat{O}_P$. These are: entry materials, manufacturing technology, and manufacturing organization and technique.

Entry materials are represented by the vector $\overrightarrow{S}$. Its components are represented by the following vectors:

(1) Quality of the production raw materials $\overrightarrow{S_1}$
(2) Material composition (recipe) $\overrightarrow{S_2}$
(3) Proper setting of efficiency norms $\overrightarrow{S_3}$

The three components are represented as vectors here. Modules of these vectors should be calculated using statistical algorithms, adequate to the operational goals. The final vector $\overrightarrow{S}$ is represented as the sum of component vectors, as follows:

$$\overrightarrow{S} = \overrightarrow{S_1} + \overrightarrow{S_2} + \overrightarrow{S_3} \tag{1}$$

The vector $\overrightarrow{S}$ can be seen in Figure 2.

Manufacturing technology, with the assigned vector $\overrightarrow{T}$, contains the following components with their respective vectors:

(1) Selection of optimal process parameters $\overrightarrow{T_1}$
(2) Stability of the assumed manufacturing processes $\overrightarrow{T_2}$
(3) Process efficiency control, including:
   - that of individual process phases $\overrightarrow{T_3}$
   - that of interoperational semi-finished product quality $\overrightarrow{T_4}$
   - that of the proper setting of efficiency norms $\overrightarrow{T_5}$

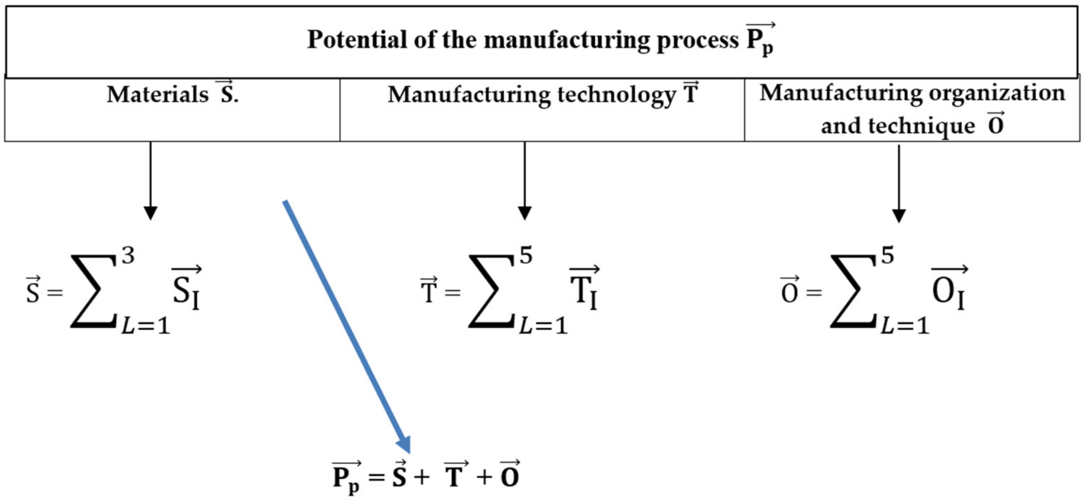

Figure 2. Component vectors $\vec{S}$, $\vec{T}$, $\vec{O}$ of the manufacturing process potential vector. Source: own elaboration.

The components of the vector $\vec{T}$ should be calculated using statistical algorithms, adequate to the operational goals. The final vector T has the following final form:

$$\vec{T} = \vec{T}_1 + \vec{T}_2 + \vec{T}_3 + \vec{T}_4 + \vec{T}_5 \quad (2)$$

The vector $\vec{T}$ can be seen in Figure 2.

Manufacturing organization and technique is the third factor of the manufacturing potential, and is represented by the vector $\vec{O}$ with the following component vectors:

(1) Staff qualification and involvement $\vec{O}_1$
(2) Functionality and reliability of manufacturing machinery $\vec{O}_2$
(3) Technological progress $\vec{O}_3$
(4) Hygienic and sanitary conditions $\vec{O}_4$
(5) Conditions for storage and shipment $\vec{O}_5$

The vector $\vec{O}$ is the sum of the five abovementioned component vectors and is represented as:

$$\vec{O} = \vec{O}_1 + \vec{O}_2 + \vec{O}_3 + \vec{O}_4 + \vec{O}_5 \quad (3)$$

The vector $\vec{O}$ can be seen in Figure 2.

The vector components can be defined as vectors whose modules are calculated from properly constructed statistical algorithms.

3.2. Normalized Form of the Manufacturing Process Potential Vector

The vector of the manufacturing process potential $\vec{P}_p$ is the sum of the abovementioned vectors $\vec{S}$, $\vec{T}$, and $\vec{O}$ (cf. Figure 2):

$$\vec{P}_p = \vec{S} + \vec{T} + \vec{O} \quad (4)$$

Further analysis of the assessment of the value of component vector modules will be easier if formula (4) is normalized.

In a rectangular grid, we receive—from vector $\vec{A}$ on the *x*-axis and from $\vec{B}$ on the *y*-axis—formulas for normalized component vectors: $\vec{S_z}$, $\vec{T_z}$, $\vec{O_z}$, and $\vec{P_{P_z}}$, the resultant vector:

$$\vec{S_z} = C_s\vec{A} + D_s\vec{B} \tag{5}$$

$$\vec{T_z} = C_T\vec{A} + D_T\vec{B} \tag{6}$$

$$\vec{O_z} = C_o\vec{A} + D_o\vec{B} \tag{7}$$

$$\vec{P_{P_z}} = \vec{A} + Dp\vec{B} \tag{8}$$

Designations of concepts

C_s—First weight value (raw material weight) for C vector $\vec{P_{P_X}}$ ε[0,1] (*x*-axis)

D_s—The first normalized (raw material value) for the D values of the vector components $\vec{P_{P_Y}}$ ε [0,1] (*y*-axis)

C_T—second weight value (production technology weight) for C vector $\vec{P_{P_X}}$ ε[0,1] (*X*-axis)

D_T—Second normalized (value of production technology) for D values of vector components $\vec{P_{P_Y}}$ ε[0,1] (*y*-axis)

C_O—the third value of weights (weight of organization and production technology) for C vector $\vec{P_{P_X}}$ ε[0,1] (*x*-axis)

D_O—Third normalized (value of organization and production technology) for the value of D of the vector components $\vec{P_{P_Y}}$ ε[0,1] (*y*-axis)

The normalized vectors are presented in Figure 3.

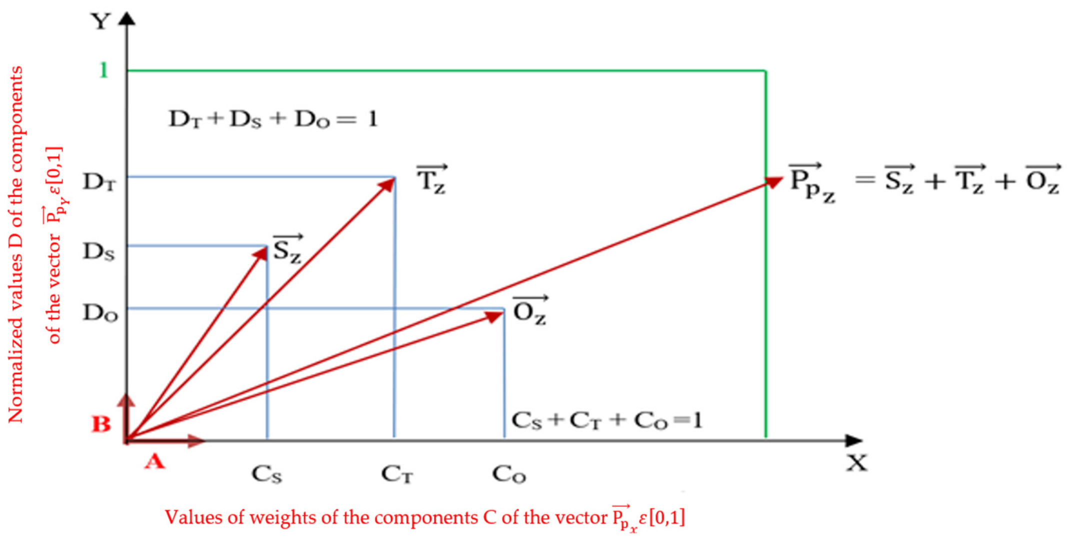

Figure 3. Normalized vector of the potential of the manufacturing process $\vec{P_{P_Z}}$. Source: own elaboration.

Values of the coordinates on the *y*-axis come from statistical algorithms, and weight values on the *x*-axis are based on experience and practice—in the case of this paper, from the baking industry.

Taking into account the above, we can show the following relations:

$$D_T + D_S + D_O = 1 \tag{9}$$

$$C_S + C_T + C_O = 1 \tag{10}$$

$$D_p = D_T + D_S + D_O \tag{11}$$

The final form of the manufacturing process potential vector $\vec{P}_{p_z}$ is:

$$\vec{P}_{p_z} = \vec{A} + (D_S + D_T + D_O) \tag{12}$$

The module of the normalized vector ought to be presented as:

$$P_{p_z} = \frac{1}{\sqrt{2}}\sqrt{1 + (D_T + D_S + D_O)} \tag{13}$$

Taking into account the relations in (13), we arrive at the final formula for the normalized form of the manufacturing process potential vector:

$$\vec{P}_{p_z} = \frac{1}{\sqrt{2}}\left[\vec{A} + (D_S + D_T + D_O)\vec{B}\right] \tag{14}$$

The module of the vector $\vec{P}_{p_z}$ is as follows:

$$P_{p_z} = \frac{1}{\sqrt{2}}\sqrt{1 + (D_S + D_T + D_O)^2} \leq 1 \tag{15}$$

The formula (14) is a vector representation of the manufacturing process potential. The module of this vector defined by the formula (15) may be its scalar measure.

Scalar values in the formulas (14) and (15) were empirically adjusted based on research and interviews with participants in the baking industry.

4. Discussion

The article's concept of a metrizable product quality assessment has vast practical implications. Its application will allow obtaining complex data on product quality. The method is a new one; so far, such an approach has not been used in order to provide metrizable product quality. It seems that, in particular, the introduction of the presented vector representation may prove useful in Industry 4.0 and the so-called Quality 4.0.

The problem of the measurement of bread production quality requires detailed digitalization of all production processes. This will lead to the implementation of Industry 4.0 principles in this industry. The authors of other publications in the area of Industry 4.0 [55–57] often speak of the necessity of digitizing manufacturing process data so they can be metrizable. In particular, literature on Quality 4.0 stresses the following issues of data digitization and the metrizability of manufacturing processes [58–64]:

(1) The application of data science and statistics—allowing for the construction of product quality models and the use of the full potential of methods such as the current paper's vector analysis of quality.
(2) Supporting technologies—sensors, measurement equipment, Internet of Things, Industrial Internet of Things, and cloud computing.
(3) Big data—collection and analysis of large pools of data in real time,
(4) Artificial intelligence—the application of AI to make complex decisions based on the collected metrizable data,
(5) Machine learning—allowing for the discovery of information patterns and heuristics to be used in decision-making.

The issues of weights in the abovementioned Quality 4.0 were researched by the team led by A. Carvalho [65]. This research also pointed to the need to collect, process, and measure data in order to transform quality management towards Quality 4.0. Those mentioned issues are also very important in the case of bread production, and we need to address them to increase the quality of products.

The novelty of the concept in this study comes from the application of an advanced mathematical apparatus for the purposes of product quality analysis. However, practical applications of this method will not be possible before the Fourth Industrial Revolution because of the insufficient level of digitization of manufacturing processes [66,67]. Only after the emergence of Industry 4.0 and Quality 4.0 with the accompanying phenomena will the application of this kind of mathematically advanced method be possible in business practice.

This publication focuses on the baking industry, but the method has potential for other branches of industry, following adjustments.

The method of quality assessments can be used in the baking industry. There are some methods used to assess product quality in this industry—for example, analyzing baking quality [35]. However, those methods are directed only at the quality of some technical aspects of the products. There is not in the literature a method assessing the all aspects related to the functioning of the baking industry from a managerial and production point of view. It is concluded that this method could be a contribution towards the transformation of the baking industry, towards Industry 4.0. In Industry 4.0, we digitalize all data, and analyze them using big data or artificial intelligence methods [65–68]. It is concluded that this method based on real data from bakeries will speed up the implementation of Industry 4.0 therein. To use the method proposed in the paper, we need to digitalize all the production processes and managerial processes to obtain enough data to implement them in the vector analysis. That digitalization will be an important step towards the Industry 4.0 implementation. The use of a systematic assessment of product quality based on vector analysis can be a one of the analyses used in many organizations as an element of Industry 4.0 solutions.

The new rules of the measurability of factors formulated by the authors in the article refer to a certain part of the gold standard method, and bread quality research is focused on the following features:

(a) Nutritional value—determined by the general chemical composition,
(b) Palatability—determined mainly by the composition and quality of the raw materials used,
(c) Healthiness—defined as the lack of risks to the consumer's health,
(d) Attractiveness—determined by shape, color, and packaging,
(e) Durability—ensuring storage without quality changes,
(f) Freshness—equated with flexibility, smell, and taste of the bread.

5. Conclusions

The specialist literature has not yet produced a publication on the concept of a metrizable method of product quality assessment in the bakery industry. The authors, in the course of writing the article, could not find, for comparison, other examples of comparable research and publications. The concept analyzed in the article is new and innovative—it can be used in a wide range of production processes (including Industry 4.0 and Quality 4.0). As we said, this type of analysis has not been used in management science, but the vector analysis method itself has been used to analyze problems in technical sciences. This conceptualization based on vector analysis was used in many technical analyses—for example, in acoustics [20]. However, our analysis of international databases (Web of Science and Scopus) suggests that the concept has not been used in management science. Due to the specifics of managerial science, we could not just translate the vector analysis used in technical sciences, but we prepared a new, extensive version based on the same mathematical concept (vector analysis) but adjusted to the specifications of industrial management related problems.

The main value of the paper is the presentation of new, extensive method for systemic assessments of product quality based on vector analysis in industrial organizations. We used the example of the baking industry. We concluded that it is a contribution to management science, especially in the field of quality management, because this approach was not hitherto used in business and is not described in relevant international literature.

The results of the paper support hypothesis H1—we conclude that it is possible to use the prepared method in baking industry. It gives organizations the possibility to assess their own products and also compare theirs those others' products.

The metrizable idea of systemic product quality assessment is required for analysis and prognosis of modern quality trends. The systemic approach to the description of a manufacturing process in the context of improving final product quality allows the application of the presented concept in any manufacturing business, provided that the determinants of product quality are defined on a branch-by-branch or product-by-product basis.

The presented concept of a model of systemic product quality analysis has a metrizable representation in two forms. One of them, seemingly most adequately reflecting the actual product quality, is the manufacturing process potential vector defined by the formulas (4) and (14). This vector is in fact the equivalent to the state of quality. Its module is defined by the formula (15). Vector [14] takes into account the dominant factors from the manufacturing process deciding the quality of the bread, including the important elements of managing a manufacturing process.

The method of defining the values of empirical factors in formula (15) needs further development with research and financial outlays. In the future, the method will be used in organizations in the baking industry to assess their production systems and compare them. Additionally, this method can be modified and used in the other industries. Each industry is different, and the method will need adjustment to the particular industry's conditions, but it is concluded that vector analysis-based systematic assessments of product quality can be used in other industries. We shall prepare another version of the method for another industry and attempt to report on its use in practice.

Author Contributions: Conceptualization, R.D. and R.W.; methodology, R.D.; validation, R.D. and R.W.; formal analysis, R.D.; investigation, R.W.; resources, R.D.; data curation, R.W.; writing—original draft preparation, R.D.; writing—review and editing, R.D. and R.W.; visualization, R.W.; supervision, R.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding. Financing form own resources.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

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

References

1. Worth, M.J. *Nonprofit Management*, 6th ed.; SAGE: Los Angeles, CA, USA, 2020; pp. 233–291. Available online: https://www.ebooks.com/en-ax/book/210040209/nonprofit-management/michael-j-worth/ (accessed on 17 July 2021).
2. Robbins, S.; Coulter, M.; De Cenzo, D. *Fundamentals of Management*, 10th ed.; Pearson: London, UK, 2016; pp. 115–128.
3. Rothaermel, F. *Strategic Management: Concepts*; McGraw-Hill: New York, NY, USA, 2021; pp. 2–18.
4. Ładoński, W.; Szołtysek, K. *Quality Management. Part 3. Methods of Shaping Quality in an Organization*; Publishing House of the University of Economics in Wroclaw: Wroclaw, Poland, 2008; pp. 45–58.
5. Liker, J.K. *The Toyota Way—14 Management Principles from the World's Greatest Manufacturer*; McGraw-Hill: New York, NY, USA, 2004; pp. 103–109.
6. Lock, D. *Quality Management Manual*; Scientific Publisher PWN: Warsaw, Poland, 2012; pp. 55–61.
7. Oakland, J.S.; Oakland, R.J.; Turner, M.A. *Total Quality Management and Operational Excellence: Text with Cases*, 5th ed.; Routledge: London, UK, 2020; pp. 345–376.
8. Drozd, R.; Wolniak, R. *Metrisable Assessment of the Course of Stream-Systemic Processes in Vector Form in Industry 4.0*; Springer: Berlin/Heidelberg, Germany, 2021; pp. 1–16.
9. Michlowicz, E. Logistics systems and systems theory. In Proceedings of the 13th Applied Logistics Conference "Total Logistics Management", Zakopane, Poland, 1–5 June 2009.
10. Newton, R. *The Management Book*; FT Publishing International: Upper Saddle River, NJ, USA, 2012; pp. 223–267.

11. Cempel, C. *Systems Theory and Engineering—Principles of Applying Systems Thinking*; Institute of Sustainable Technologies: Radom, Poland, 2006; pp. 34–51.
12. Pogorzelski, W. *Systems Theory and Optimization Methods*; Warsaw University of Technology Publishing House: Warsaw, Poland, 2009; pp. 34–37.
13. Powierża, L. *Elements of Systems Engineering*; Publishing House of the Warsaw University of Technology: Warsaw, Poland, 2007; pp. 18–49, 89–93, 105–113.
14. Sałaciński, T. *Quality Engineering in Manufacturing Technology*; Technical University of Warsaw: Warsaw, Poland, 2019; pp. 190–210.
15. Schonberger, R.J. *World Class Manufacturing*; Free Press: New York, NY, USA, 2008; pp. 112–145.
16. Jung, M.; Glardon, R. *Manufacturing Operations Management*; World Scientific: Singapore, 2018; pp. 160–190.
17. Kalpakjian, S. *Manufacturing Engineering and Technology*; Pearson Education Centre: London, UK, 2013; pp. 670–724.
18. Wang, C.-H.; Dang, T.-H.; Nguyen, N.-A. A Computational Model for Determining Levels of Factors in Inventory Management Using Response Surface Methodology. *Mathematics* **2020**, *8*, 1210. [CrossRef]
19. Wang, C.-H.; Nguyen, N.-A.; Dang, T.-H. Solving Order Planning Problem Using a Heuristic Approach: The Case in a Building Material Distributor. *Appl. Sci.* **2020**, *10*, 8959. [CrossRef]
20. Wang, C.-H.; Chen, D.; Huang, H.; Zhan, W.; Lai, X. MIMO LS-SVR-Based Multi-Point Vibration Response Prediction in the Frequency Domain. *Appl. Sci.* **2020**, *10*, 8784. [CrossRef]
21. Martinez-Comesaña, M.; Febrero-Garrido, L.; Granada-Alvarez, E.; Martinez-Torrez, J.; Martinez-Mariño, S. Heat Loss Coefficient Estimation Applied to Existing Buildings through Machine Learning Models. *Appl. Sci.* **2020**, *10*, 8968. [CrossRef]
22. Wolniak, R.; Skotnicka-Zasadzień, B. Developing a Model of Factors Influencing the Quality of Service for Disabled Customers in the Condition s of Sustainable Development, Illustrated by an Example of the Silesian Voivodeship Public Administration. *Sustainability* **2018**, *10*, 2171. [CrossRef]
23. Bartosiewicz, A.; Burzyńska, J.; Januszewicz, P. Polish Nurses' Attitude to e-Health Solutions and Self-Assessment of Their IT Competence. *J. Clin. Med.* **2021**, *10*, 4799. [CrossRef]
24. Tsuen-Ho, H.; Sen-Tien, H.; Jia-Jeng, H. Developing Universally Applicable Service Quality Assessment Model Based on the Theory of Consumption Values, and Using Fuzzy Linguistic Preference Relations to Empirically Test Three Industries. *Mathematics* **2021**, *9*, 2608. [CrossRef]
25. Dennis, P. *Lean Production Simplified*, 3rd ed.; Taylor & Francis Inc.: London, UK, 2015; pp. 88–112.
26. Althaus, B.; Blanke, M. Development of a Freshness Index for Fruit Quality Assessment—Using Bell Pepper as a Case Study. *Horticulturae* **2021**, *7*, 405. [CrossRef]
27. Sannakustim, S.; Laitinen, M.; Sontag-Strohm, T. Baking Quality Assessment of Twenty Whole Grain Oat Cultivar Samples. *Foods* **2021**, *10*, 2461. [CrossRef]
28. Neshitov, A.; Tyapochkin, K.; Smorodnikova, E.; Pradvin, P. Wavelet Analysis and Self-Similarity of Photoplethysmography Signals for HRV Estimation and Quality Assessment. *Sensors* **2021**, *21*, 6798. [CrossRef] [PubMed]
29. Selmy, S.A.H.; Al-Aziz, S.H.A.A.; Jimenez-Ballesta, R.; Garcia-Navarro, F.J.; Fadl, M.E. Soil Quality Assessment Using Multivariate Approaches: A Case Study of the Dakhla Oasis Arid Lands. *Land* **2021**, *10*, 1074. [CrossRef]
30. Chryssolouris, G. *Manufacturing Systems*; Springer: Berlin/Heidelberg, Germany, 2015; pp. 251–294.
31. Bhowmik, S.; Jagadish Gupta, K. *Modeling and Optimization of Advanced Manufacturing Processes*; Springer: Berlin/Heidelberg, Germany, 2018; pp. 380–420.
32. Bijan, Y.; Yu, J.; Stracener, J.; Woods, Y. Systems Requirements Engineering—State of the methodology. *Syst. Eng.* **2012**, *16*, 267–276. [CrossRef]
33. Drozd, R.; Piwnik, J. *Metrisability of Managing of Stream-Systemic Processes*; Series No. 151; Scientific Papers of Silesian University of Technology, Organization and Management: Warsaw, Poland, 2021; pp. 145–156.
34. Drozd, R.; Piwnik, J. The influence of robotization on the reliability of the production process in the bakery industry. *Sci. Didact. Equip.* **2019**, *3*, 221–228.
35. Drozd, R. Functional model of the impact of factors on product quality in the baking industry. *Sci. Didact. Equip.* **2020**, *3*, 173–180.
36. Drozd, R. The role of robotisation in improving bakery product quality industry. *Sci. Didact. Equip.* **2020**, 261–267. Available online: http://abid.cobrabid.pl/download.php?ma_id=4265&o=1 (accessed on 15 July 2021).
37. Fast, L.E. *The 12 Principles of Manufacturing Excellence: A Lean Leader's Guide to Achieving and Sustaining Excellence*, 2nd ed.; CRC Press: Boca Raton, FL, USA; Taylor@Francis Group: London, UK; Productivity Press: London, UK, 2015; pp. 211–267.
38. Groover, M.P. *Fundamentals of Modern Manufacturing: Materials, Processes and Systems*, 7th ed.; Wiley: Hoboken, NJ, USA, 2020; pp. 51–98.
39. Jawad, A. *Production Planning and Control with SAP ERP*; Rheinwerk Verlag: Bonn, Germany, 2016; pp. 830–890.
40. Lefteri, C.H. *Making It: Manufacturing Techniques for Product Design*, 3rd ed.; Laurence King: London, UK, 2019; pp. 120–145.
41. Miller, W.B.; Schenk, V.L. *All I Need to Know about Manufacturing I Learned in Joe's Garage: World Class Manufacturing Made Simple*; Bayrock Press: Fort Collins, CO, USA, 2004; pp. 56–89.
42. Deming, E.W.; Latzko, W.J.; Saunders, D.M. *Four Days with Dr. Deming—Modern Management Theory*; WNT: Warsaw, Poland, 1998; pp. 274–288.
43. Garvin, D.A. *What Does Product Quality Really Mean*; Sloan Management Review: Cambridge, UK, 1994; pp. 123–145.
44. Kinicki, A.; Williams, B. *Management. Practical Introduction*; McGraw-Hill Education: New York, NY, USA, 2019; pp. 45–57.

45. Pyzdek, T.; Keller, P. *The Handbook for Quality Management, Second Edition: A Complete Guide to Operational Excellence*, 2nd ed.; McGraw-Hill Education: New York, NY, USA, 2013; pp. 119–152.
46. Sikora, T.; Strada, A. *Safety and Quality Assurance and Management Systems in Food Industry: An Overview*; The Food Industry in Europe, Agricultural University of Athens: Athens, Greece, 2005; pp. 89–95.
47. Ambroziak, Z. The quality of bread. In *Baking—Recipes, Standards, Advice and Legal Regulations*; Publisher Organization and Management: Warsaw, Poland, 2002; pp. 109–113.
48. Dziugan, P. Jakość I warunki produkcji pieczywa w Polsce. *Przegląd Piek.* **2006**, *12*, 14–15.
49. Ellis, C.J. *The Quality Bread Baking Methods and Recipes for Beginners: Detailed Guide to Baking Yeast, No-Yeast and Favorite Bread Recipes for Beginners*; Independen Publishing: New York, NY, USA, 2020.
50. Crandall, W.R.; Parnell, J.A.; Spillan, J.E. *Crisis Management: Leading in the New Strategy Landscape*; SAGE Publishing: New York, NY, USA, 2019.
51. Drucker, P.F. *Management: Tasks, Responsibilities, Practices*; Elsevier Science & Technology: Amsterdam, The Netherlands, 1999; pp. 101–135.
52. Khan, M. *Principles of Management & Marketing*; Independently Published: New York, NY, USA, 2021.
53. Drozd, R.; Piwnik, J. The concept of stream and system reliability on the example of the bakery industry. *Apar. Badaw. I Dydakt.* **2019**, *24*, 257–264.
54. Drozd, R. *Concept of Managing Quality in Baking Industry, in Vector Representation*; Series No. 151; Scientific Papers of Silesian University of Technology, Organization and Management: Warsaw, Poland, 2021; pp. 157–172.
55. Foidl, H.; Felderer, M. Challenges of Industry 4.0 for Quality Management. In *Innovations in Enterprise Information Systems Management and Engineering*; Felderer, M., Piazolo, F., Ortner, W., Brehm, L., Hof, H.J., Eds.; ERP Future 2015; Lecture Notes in Business Information Processing; Springer: Berlin/Heidelberg, Germany, 2016; Volume 245. [CrossRef]
56. Saraiva, M.; Novas, J.C.; Gomes, P.G. How Communication and Control Processes Improve Quality. In *Achieving Competitive Advantage through Quality Management*; Peris-Ortiz, M., Álvarez-García, J., Rueda-Armengot, C., Eds.; Springer: Cham, Switzerland, 2015; pp. 219–231.
57. Wang, S.; Wan, J.; Li, D.; Zhang, C. Implementing Smart Factory of Industrie 4.0: An Outlook. *Int. J. Distrib. Sens. Netw.* **2015**, *12*, 3159805. [CrossRef]
58. ASQ. Industry and Quality 4.0: Bringing Them Together. *Qual. Mag.* **2018**. Available online: https://www.qualitymag.com/articles/95011-industry-and-quality-40-bringing-them-together (accessed on 15 July 2021).
59. Jacob, D. Top 4 Reasons to Update to Quality 4.0. 2021. Available online: https://blog.lnsresearch.com/top-4-reasons-to-update-to-quality-4.0 (accessed on 15 July 2021).
60. Radziwill, N. Designing a Quality 4.0 Strategy and Selecting High-Impact Initiatives. In *ASQ Quality 4.0 Summit, Disruption, Innovation and Change*; ASQ: Dallas, TX, USA, 2018.
61. Sisodia, R.; Villegas-Forero, D. *Quality 4.0—How to Handle Quality in the Industry 4.0 Revolution*; Chalmers University of Technology: Gotheburg, Sweden, 2020.
62. Söderqvist, L. Quality 4.0 Hetast Internationellt. Kvalitets Magasinet. 2021. Available online: https://kvalitetsmagasinet.se/quality-4-0-hetast-i-kvalitetsbranschen (accessed on 15 July 2021).
63. Watson, G.H. The ascent of Quality 4.0: How the new age of quality might look like in 20 years. *Qual. Prog.* **2019**, *52*, 24–30.
64. Carvalho, A.V.; Enrique, D.V.; Chouchene, A.; Charrua-Santos, F. Quality 4.0: An overview. *Procedia Comput. Sci.* **2021**, *181*, 341–346. [CrossRef]
65. Gajdzik, B.; Wolniak, R. Digitalisation and Innovation in the Steel Industry in Poland-Selected Tools of ICT in an Analysis of Statistical Data and a Case Study. *Energies* **2021**, *14*, 3034. [CrossRef]
66. Miśkiewicz, R.; Wolniak, R. Practical application of the Industry 4.0 concept in a steel company. *Sustainability* **2020**, *12*, 5776. [CrossRef]
67. Gajdzik, B.; Wolniak, R. Transitioning of steel producers to the steelworks 4.0—Literature review with case studies. *Energies* **2021**, *14*, 4109. [CrossRef]
68. Stawiarska, E.; Szwajca, D.; Matusek, M.; Wolniak, R. Diagnosis of the maturity level of implementing industry 4.0 solutions in selected functional areas of management of automotive companies in Poland. *Sustainability* **2021**, *13*, 4867. [CrossRef]