

Article

Identification of Barriers to Sustainable Manufacturing Implementation—The Perspective of Manufacturers of Parts and Components for Agricultural Transport

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Abstract: Sustainable manufacturing involves executing manufacturing processes in a way that follows the sustainable development principles, striving to combine economic, ecologic and social goals. The expected benefits of sustainable manufacturing are a lower cost and an improved environmental impact and well-being of employees. The main goal of the research was to identify barriers to the implementation of sustainable manufacturing principles. Achieving the main goal required the implementation of partial goals: (G1) designing the research tool based on the specific features of sustainable manufacturing identified based on the literature research; (G2) identifying of barriers that limit and/or prevent the implementation of sustainable manufacturing; and (G3) assessing the significance of individual factors limiting (preventing) implementation. The research was conducted in the agricultural transport sector and the subjects of the research were manufacturers of parts and subassemblies for agricultural transport. The ranking of limitations and barriers enables the definition of recommendations for companies willing to implement sustainable manufacturing concepts.

Keywords: sustainable manufacturing; agricultural transport means; sustainable development



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1. Introduction

The management paradigm that dominated in the past, i.e., profit maximization, although it is still often followed, is nowadays competing with a desire to achieve various goals resulting from the expectations of individual stakeholder groups [1]. Moreover, the classic paradigms of visionary leadership, which takes into account the unpredictability of the environment, or organic leadership, which additionally assumes the ability of self-organization of systems and complexity, are no longer leading [2]. The consequence of this paradigm shift is a new business environment in which opportunities for the flourishing of intelligent organizations are emphasized [3] and flat structures capable of effective communication, continuous learning [4], and flexible operation [5] are promoted. From the perspective of management, this forces an evolution in the culture and changes in the structure, strategy and communicating schemes. It is therefore necessary to adapt traditional organizational forms to new requirements.

Taking into account changes such as globalization, growing environmental dynamics, hyper-competition, supply chain disruptions [6], distribution evolution [7] or information technologies development, and significant progress in science, new paradigms [8], useful in the changing and complex conditions of the operation of modern organizations, are needed. Hence, the authors point to the concept of sustainable manufacturing as the approach that responds to contemporary challenges and follows legal regulations. Sustainable manufacturing (SM) involves manufacturing products in economically sound processes that minimize negative environmental impacts while conserving energy and natural resources,

while at the same time enhancing employee, community and product safety. However, since the implementation of sustainable manufacturing is not common, the authors aim to identify the barriers related to its implementation. The research is conducted among manufacturers of parts and subassemblies for means of agricultural transport, as agriculture is a sector crucial for the economy. Companies in this sector are aware of the great development challenges resulting from macro-trends and understand the need to implement the concept of sustainable manufacturing, yet a number of barriers limiting this adaptation are recognized. Some of the barriers are internal and result from internal beliefs, as well as the organizational or technological culture, while some are external and result from the existing institutional and legal environment.

In light of the above, this topic seems to be interesting for both academics and business practitioners. The research problem, namely the identification of the barriers to the implementation of sustainable manufacturing, is important. Its solution may significantly contribute to developing solutions enabling the elimination or minimization of the implementation barriers to sustainable manufacturing.

The research concept adopted in this work deals with the gap identified in the preliminary literature reviews, indicating a lack of research in the agricultural machinery sector. The research results will contribute to filling in the recognized gap. The authors stipulate that the described empirical studies do not provide grounds for generalization and drawing conclusions about the general population, and the obtained results only indicate the condition and dependencies within manufacturing enterprises classified within the surveyed sector.

2. Research Framework

2.1. Research Problem Definition

Undoubtedly, as a consequence of new operating conditions, new research perspectives are emerging, combining social sciences with technical fields. Particularly in recent years, interdisciplinary work related to new concepts, such as the concept of a sustainable organization, has become more and more visible in the field of science. Research on the managerial aspects (barriers to implementation of a new solution) of manufacturing processes (manufacturing of parts and subassemblies for agricultural transport means) benefits from interdisciplinary knowledge and research published by researchers representing a wide range of disciplines and fields of science, e.g., research on the recycling of transport means [9–11], the means of transport exploitation [12], the organization of manufacturing processes [13,14], the sustainability of processes [15], sustainable management [16,17], human resources management [17–19], and leadership and development [20,21], varying from an operational to a strategic perspective and from technical to social aspects. Although the concept of sustainable development appears to have been introduced and generally characterized, it is still not fully recognized. The wide interest in the concept among theoreticians and practitioners has resulted in numerous publications in this field; however, research on the sustainable manufacturing of parts and subassemblies for agricultural means of transport is limited, with fewer than five publications on this topic identified in the Scopus database as of January 2024.

Summing up, there is a shortage of scientific studies on the barriers for sustainable manufacturing implementation in companies manufacturing parts and subassemblies for agricultural means of transport.

2.2. Research Goal and Research Questions

The constitutive aim of this work is to identify barriers to the implementation of the concept of sustainable manufacturing and the factors determining them, based on the literature on the subject. Theoretical research should be complemented by empirical research, namely a study conducted among selected production companies operating in the agricultural machinery sector (specialization: production of parts and technical subassemblies for means of agricultural transport). The identification of barriers is based

on the micro-to-macro approach where authors, based on theoretical and empirical research, recognize a specific parameter (micro) which is the key to explaining the phenomena at the level of the entire implementation process (macro).

The main goal was deconstructed into partial goals of a theoretical, methodological and practical nature.

The theoretical goals focused on the recognition of the general concept of sustainable manufacturing, which was followed by defining a catalog of barriers that significantly affect the process of implementing the sustainable manufacturing concept. The methodological purposes included hierarchization of the barriers identified. The practical goal was the validation of the developed hierarchy of factors determining the implementation of the concept of sustainable manufacturing (potential barriers). The expected result from partial goal realization was the identification of factors crucial for sustainable manufacturing implementation by manufacturers of parts and subassemblies for means of agricultural transport in Poland.

In the context of the conducted analyses, the following research questions were formulated:

RQ1. *What are the barriers described in the literature to the implementation of sustainable manufacturing?*

RQ2. *Are the literature review results, experts' opinions and opinions of manufacturers of parts and subassemblies for means of agricultural transport in Poland on the recognized barriers coherent?*

RQ3. *What is the hierarchy of importance for manufacturers of parts and subassemblies for means of agricultural transport in Poland of particular sustainable manufacturing implementation barriers?*

The research questions will be answered in the course of our theoretical and empirical research. The subjects of this study are manufacturing companies operating in the agricultural transport sector, while the objects of the study are the barriers of sustainable production implementation.

3. Materials and Methods

In the conducted research, a three-stage research procedure was used. The procedure is presented in Figure 1.

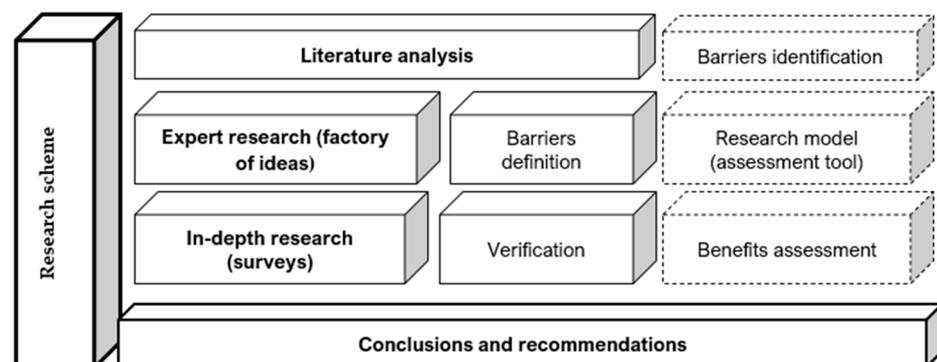


Figure 1. Research realization scheme. Source: Own work.

Figure 1 presents a three-stage approach starting with literature analysis, which allowed for setting the basis for the research procedure by means of the identification of barriers to sustainable manufacturing implementation. The barriers identified were presented in the form of a list, which was validated by the experts in the expert research conducted with a scientific regime and the experience-based commitment of the researchers involved. The validated list of barriers was used to design the assessment tool that enabled the hierarchization of the barriers from a practical perspective in the next stage of the research procedure. The opinions of representatives of manufacturers of parts and subassemblies for means of agricultural transport were collected and analyzed. Based on the opinions collected, conclusions and generalizations were made.

4. Research Results

4.1. Literature Query

The key element of the authors' work was a review of the literature on the subject, including studies in the field of social sciences, as well as engineering and technology.

The literature analysis started with the identification of works on barriers to sustainable manufacturing. The expert method of literature review, which does not require the authors to describe the defined search criteria, making literature studies arbitrary, showed that sustainable manufacturing implementation barriers is a topic that is included under various headings and in various combinations. Due to the fact that the databases do not include scientific texts written in a language other than English and at the same time do not have bibliometric data in this language, which could constitute a substantive contribution to this work, a systematic review of the literature was abandoned. Yet, with the expert search, the identified publications were reviewed and a list of barriers were identified.

The next step was to search for specific barriers in the context of sustainable manufacturing to confirm the importance of the barriers. At this stage, both Polish- and English-language texts was used. The analysis was carried out in four phases. Hence, key factors (barriers) were extracted from the available texts.

The barriers identified in the literature review included the following [22]:

- Weak legislation [23–27];
- Lack of government support [28,29];
- Low public and peer pressure [26,30–32];
- Misconceptions and uncertain financial benefits [26,31,33–36];
- Low customer awareness and demand for sustainable products [26,31,37–42];
- Complexity in the design of sustainable products, processes, and systems [26,29,31,33,43–56];
- Management complexity [29,49,57–59];
- Low top management commitment, a lack of leadership and technical expertise [26,31,52,60–64];
- Lack of sustainable manufacturing resources and infrastructure [31,65–67];
- Financial constraints [26,29,31,32,68–71];
- Lack of awareness, training, education, and rewards systems for employees [24,31,36,51,61,72–75];
- Technological risk [76–79];
- Lack of updated information and difficulty in the evaluation of system performance throughout the life cycle [26,28,29,47,57,59,79–82];
- Resistance to change [26,33,83,84];
- Lack of cooperation and mutual trust among management, employees, and value-chain partners [26,59,73,80];
- Low employee commitment, involvement, and empowerment [24,52,57,62,73,80,85];
- Undeveloped organizational culture and organizational structure [31,33,36,60,79,85–90];
- Lack of teamwork [62,71,81,91–93];
- Cross-functional/inter-departmental conflict [36,65,74,80,94–98];
- Poor partnership [29,59,87,99–103];
- Lack of continuous improvement culture [52,74,104–106];
- Lack of supplier integration, supplier awareness, and supplier commitment [24,29,31,33,36,41,47,51,57,60,61,72,73,75,80,82,87,107–109].

Secondly, through logical analysis, repeated thematic component areas were distinguished. Then, the corresponding content was assigned to each factor. In the final stage, the frequency of occurrence of individual factors was examined and conclusions were drawn, which were presented during an organized creative thinking session with experts in sustainable manufacturing field.

4.2. Factory of Ideas

The authors conducted the expert-based research, collecting opinions of purposefully selected experts in the relevant field. The number of experts and the composition of

the group were related to the breadth of the problem to be solved and the credibility of the assessments. The criteria for selecting the experts were as follows: expertise in the manufacturing of parts and subassemblies for means of agricultural transport; experience in management; and interest in sustainable manufacturing. The size of the problem to be solved determined the need to include only specialists in the field (management and production engineering and transport) in the expert analysis; however, features such as creativity (ability to solve creative tasks), attitude to expertise, conformism, constructive thinking and self-criticism were also considered.

It was assumed that a debate in a group of experts may lead to (1) the creation of new knowledge and (2) the verification of the accuracy of the selection of factors developed on the basis of previous research and definitions reflecting them. To conduct the research, eighteen experts were appointed, consisting of owners (9 people), senior managers (5 people), and middle-level employees (2 people) of small (27.78%), medium (55.56%) and large (5.56%) production companies operating in the sector of agricultural machinery in Poland (manufacturers of parts and technical subassemblies for means of agricultural transport) and representatives of two scientific units (11.11%). Most of the experts were between 41 and 50 years of age (33.33%); 27.78% of the experts were aged below 40 years, 16.67% of the experts were between 51 and 60 years old, while 22.22% were over 60 years old. The group of people with a university degree definitely prevailed among the experts (77.78%); 16.67% had secondary education, while 5.56% had vocational education.

Based on the research approaches presented in the literature on the subject [106–108], the expert debate was based on a proprietary method. It was assumed that the search begins with the most general formulation of the problem, then the issues should be more and more precise. This was conducive to a multi-directional search, and at the same time it enabled the overcoming of potential barriers appearing when specifying the problem. As part of this session, a list of barriers identified in the implementation of the idea of sustainable manufacturing was specified (and used in the next stage of the research).

The presented constructs were concepts that were understandable by the expert group [109]. They were concepts designed to organize knowledge and guide empirical research on a selected aspect of reality [110]. Validation of their content—presented in a later part of this study—therefore refers to the extent to which the measurement scale reflects the selected semantic field of the construct, i.e., its content [111]. Thus, it contributes to a reduction in semantic problems.

4.3. In-Depth Research

The next step of the research was comparing the list of identified barriers with the opinions of companies involved in the manufacturing of sub-assemblies and parts for means of agricultural transport. Business practitioners were asked to take part in a survey to verify the list of barriers and give additional insights to improve our understanding of the nature and sources of the barriers identified. Seventy-four respondents participated in the survey, representing the companies involved. Among the surveyed enterprises, there were producers of agricultural tractors, cars and trailers and self-propelled machines used for harvesting fruit plants and vegetables.

For the purposes of collecting statistical material, a questionnaire was prepared, and the data collection process itself was carried out using the CASI technique.

The majority of surveyed enterprises had only Polish capital (77.03%), while 16.22% had mixed capital, and only 6.76% had solely foreign capital. Most of the surveyed entities were natural persons conducting business activities (45.95%), and there was also a significant presence of limited liability companies (28.38%) and civilian firms (6.76%). The participation of joint-stock companies (1.35%), general partnerships (9.46%), and limited partnerships (8.11%) was relatively low.

Most of the companies that took part in the survey were small to medium-sized businesses, with the majority of them employing between 10 and 50 employees. The vast

majority of enterprises had an established position in the market and had been operating for many years; 64.86% had been operating for at least 11 years.

The majority of surveyed companies primarily operated within the domestic and European markets, while 25.68% operated globally. The survey was mainly filled out by individuals at the highest management level of the company, including owners and co-owners, persons from the management board, as well as senior and middle management.

A noteworthy number of respondents (44.59%) had a master's degree, and a considerable proportion had completed post-graduate studies. The respondents were mainly aged between 45 and 54, with significant representation from the 36–44 and 55–65 age groups.

The respondents demonstrated extensive experience in the sector, with 60.81% having more than 15 years of work experience.

In this part of the study, an attempt was made to verify the theoretical assumptions—and those resulting from expert research—about the impact of certain factors on the limitations in the implementation of the idea of sustainable manufacturing (Table 1). The list of barriers was presented to the respondents and they were asked to assess the importance of each of the barriers from the lowest (1) to the highest (5).

This verification was preceded by a thorough analysis of the concept of a sustainable organization together with an indication of the direction of its definition and a thorough analysis of the methods of its measurement and application.

First of all, basic descriptive statistics were determined for all analyzed implementation barriers (in total, respondents assessed twenty-five definitions on a five-point Likert scale, with the value 1 meaning a definitely low barrier (no impact) and 5 indicating a definitely high barrier). Table 1 presents the assessed barriers listed in descending order, based on the arithmetic mean value of respondents' indications. Due to the limited possibility of presentation, the presentation of the standard deviation, median, mode, minimum and maximum values was abandoned.

It can be noticed that only in the case of three factors was the average respondents' assessment of their significance at least 3.50 (rather significant). These factors include (1) an unfavorable legal and economic environment, (2) an excessive focus on profit and disregard for environmental aspects or interpersonal relations (implementation of the concept in a technical way), and (3) an excessive focus on current affairs (lack of vision for the future).

Nine factors were assessed by the respondents as being of medium importance in the context of the impact on the implementation of the concept of sustainable manufacturing (the average oscillated between 3.03 and 3.47). The vast majority of determinants (thirteen) were assessed as constituting a rather small barrier in the context of implementation.

When analyzing the determined averages, it can be seen that the legal form, the size of the company, the age of the respondent, the length of service in the industry or the length of service in the current company do not significantly differentiate the assessment of the significance of barriers.

All of the discussed barriers on the way to implementation success should be considered together, and a good practice among initiators and leaders in implementing concepts and solutions correlated with the idea of sustainable manufacturing would be to check each time whether the planned activities related to the introduction of changes meet each of the conditions for effective implementation from the point of view of the environment.

Table 1. Barriers to the implementation of sustainable manufacturing from companies' perspectives.

Scope and Range of Activity	1	2	3	4	5	AV.
	% of Indications (Number of Indications)					
Unfavorable legal and economic environment	-	14.9 (11)	17.6 (13)	28.4 (21)	39.2 (29)	3.92
Excessive focus on profit (manufacturing efficiency), not taking into account environmental aspects and interpersonal relationships (implementing the concept in a technical way); implementation of the concept only to obtain economic and financial benefits	5.4 (4)	4.1 (3)	40.5 (30)	28.4 (21)	21.6 (16)	3.57
Excessive focus on current affairs (lack of vision for the future); preoccupation with current problems	5.4 (4)	9.5 (7)	29.7 (22)	35.1 (26)	20.3 (15)	3.55
Traditional habits, patterns, behaviors; traditional organizational culture	5.4 (4)	12.2 (9)	29.7 (22)	35.1 (26)	17.6 (13)	3.47
Cessation of implementation due to a change in priorities (short-term goals)	6.8 (5)	12.2 (9)	33.8 (25)	31.1 (23)	16.2 (12)	3.38
Weak training system on sustainable manufacturing practices	5.4 (4)	10.8 (8)	43.2 (32)	28.4 (21)	12.2 (9)	3.31
Using ready-made patterns and solutions without matching them to the conditions and context of the company	4.1 (3)	18.9 (14)	36.5 (27)	28.4 (21)	12.2 (9)	3.26
Inconsistency of goals. Misunderstanding needs. Lack of interest of companies in the implementation of projects whose benefits are considered in the long term. Little business potential.	10.8 (8)	18.9 (14)	27.0 (20)	20.3 (15)	23.0 (17)	3.26
Implementation of the concept in a random, fragmentary way	8.1 (6)	16.2 (12)	33.8 (25)	27.0 (20)	14.9 (11)	3.24
Insufficient communication about the goals and nature of the changes	4.1 (3)	16.2 (12)	40.5 (30)	32.4 (24)	6.8 (5)	3.22
No support from third parties (advice, consultation)	8.1 (6)	18.9 (14)	41.9 (31)	18.9 (14)	12.2 (9)	3.08
Resistance from employees	6.8 (5)	16.2 (12)	45.9 (34)	29.7 (22)	1.4 (1)	3.03
Lack of motivation and commitment resulting from a lack of vision and resulting benefits	8.1 (6)	24.3 (18)	39.2 (29)	24.3 (18)	4.1 (3)	2.92
Failure to take into account the real needs of enterprises	16.2 (12)	18.9 (14)	35.1 (26)	17.6 (13)	12.2 (9)	2.91
Lack of modern technological solutions; mismatch with the requirements of the environment (lack of compatibility)	14.9 (11)	16.2 (12)	40.5 (30)	21.6 (16)	6.8 (5)	2.89

Table 1. Cont.

Scope and Range of Activity	1	2	3	4	5	AV.
	% of Indications (Number of Indications)					
Unsatisfactory effects of the previous implementation attempt for companies, consisting in insufficient applicability of the proposed solutions	13.5 (10)	23.0 (17)	37.8 (28)	12.2 (9)	13.5 (10)	2.89
Staff rotation	17.6 (13)	21.6 (16)	33.8 (25)	14.9 (11)	12.2 (9)	2.82
Low awareness of the need to implement the concept of sustainable manufacturing; little understanding of the essence, especially among executive employees	14.9 (11)	16.2 (12)	41.9 (31)	27.0 (20)	-	2.81
Low awareness of potential profits (reluctance from the perspective of long-term expectations)	16.2 (12)	23.0 (17)	37.8 (28)	10.8 (8)	12.2 (9)	2.80
Improper style of implementation of individual solutions	20.3 (15)	18.9 (14)	33.8 (25)	17.6 (13)	9.5 (7)	2.77
Imposing solutions, no possibility to participate in the transformation process (blocking employee initiatives)	12.2 (9)	28.4 (21)	35.1 (26)	20.3 (15)	4.1 (3)	2.76
Excessive formalization	17.6 (13)	21.6 (16)	39.2 (29)	14.9 (11)	6.8 (5)	2.72
Lack of commitment from management	12.2 (9)	32.4 (24)	33.8 (25)	20.3 (15)	1.4 (1)	2.66
Low staff competences, lack of specialist knowledge	20.3 (15)	18.9 (14)	41.9 (31)	16.2 (12)	2.7 (2)	2.62
No financial resources; identifying transformation with large outlays	23.0 (17)	39.2 (29)	25.7 (19)	9.5 (7)	2.7 (2)	2.30

5. Conclusions

The recommendations are directly connected with the most significant barriers identified. Hence, the suggested approach when a problem of resistance to sustainable manufacturing implementation is recognized includes the following:

- Anticipating and overcoming resistance in relation to selected SM postulates of the concept;
- Implementing visionary leadership;
- Questioning “constancy”;
- Implementing an intensive and extensive communication process;
- Choosing the right moment and waiting for implementation;
- Implementing of individual SM postulates;
- Legitimizing the implemented SM postulates.

In the context of the above, a cycle of actions is outlined, which includes (1) engaging in implementation through a joint diagnosis of the situation; (2) developing a shared vision; (3) creating and gaining acceptance for the adopted vision, necessary competences and skills, and readiness to implement further actions; (4) disseminating new solutions in the enterprise; and (5) controlling the course of the transformation process and solving any problems that arise.

Hence, the transformation requires the control of key elements that form the basis for overcoming barriers preventing the implementation of selected postulates of the concept of sustainable management. Therefore, an awareness of the need to transform the company and a desire to participate in the entire process are crucial. Interdisciplinary knowledge on how to change the company and create the ability to implement the required postulates is required.

Implementing the idea of sustainable manufacturing should be an action undertaken with a specific intention and a properly designed scheme of action. The purpose of implementation is the development of the enterprise, maintaining and increasing its effectiveness or overcoming difficulties (crises) and improving results. In the context of the above, it should be emphasized that it is not only important to notice the sources and directions of changes, but also to know their nature and conditions. This skill determines the entire process of planning and implementing the concept.

It is necessary to make the need for sustainable manufacturing obvious to the company as a whole and to all of the stakeholders. The key is to create a need for change in people. This can be achieved by (1) communicating a vision, (2) gaining support for change, (3) planning change, (4) implementing specific projects, and (5) removing resistance to change. Therefore, the enterprise must develop its own operating practices, implement policy and create appropriate attitudes among its members.

The manner and scope of implementation of the sustainable manufacturing postulates is a derivative of the adopted management model. Therefore, a rational approach to the discussed issue is particularly important, including a properly constructed implementation management cycle, which requires answers to the following questions: (1) why? (indication of the reason for implementing the concept); (2) what? (defining the purpose and scope of its implementation); and (3) how? (developing an action plan for implementation and improvement activities).

The basic problem in the process of implementing the concept is to determine the successive stages. In the context of the above, it is recommended to (1) define the company's goals, both the main and subordinate ones; (2) analyze the connections and interactions with the environment (network analysis); (3) conduct an analysis of the strengths and weaknesses as well as the opportunities and threats; (4) analyze the possible directions of the implementation of the concept; (5) develop an implementation strategy; and (6) implement the chosen solution.

These are, of course, only recommendations as to the scope and direction of the implementation process in the company, but following them provides a certain guarantee of success in terms of the implemented postulates of sustainable manufacturing.

The adopted research methodology enabled the recognition of the quantitative and qualitative state of the factors constituting a barrier to the implementation of the concept of sustainable manufacturing. It should be emphasized that the results of the authors' searches are presented in the form of conclusions. They provide answers to the detailed problem questions and the main problem of the research. The solution to the research problem concerning the essence, typology and characteristics of sustainable manufacturing is presented in the form of general conclusions, as follows:

- The concept of sustainable manufacturing has not been and is still not clearly defined; over the years, the concept has evolved from a complete lack of recognition of the need for its implementation to the emergence of interest in its various dimensions;
- In the literature on the subject, there are many definitions of sustainable manufacturing (although the extensive interpretative analysis of the proposals of various researchers carried out for research purposes is not presented in this study (publishing rigor)).

Parallel to the analysis and evaluation of the literature output, techniques of creative thinking were used. On this basis, the requirements were completed in the context of building a research model. Thanks to this procedure, each time, a questionnaire was prepared, provide a tool for conducting the proper study. Suggestions, recommendations and guidelines for management practitioners resulting from the conducted empirical research are related to the proposal of changes in the field of management towards balance. Persons responsible for development are presented with specific barriers, the overcoming of which is the essence of improvement activities.

Although the work presents a certain cross-section of parameters, it should be treated as a base element for further discussions on the search for ways to stimulate improvement attitudes, thus providing an incentive to build sustainable organizations. The developed research construct is characterized by such a high degree of compatibility that it can be assumed to justify its use in the study of sectors different from the presented one. In this regard, it is postulated that future research could be undertaken in the fields of (1) increasing the degree of adaptability and adapting the method to research sectors different from the sector studied in this work (universalization of the method) and (2) systematically updating the developed set of the most important barriers.

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