SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2023
ORGANIZATION AND MANAGEMENT SERIES NO. 185

A METHOD OF ASSESSMENT OF A SUSTAINABLE PRODUCT – THE CONCEPT AND ITS IMPLEMENTATION FOR PARTS AND SUBASSEMBLIES OF AGRICULTURAL TRANSPORT MEANS

Przemysław NIEWIADOMSKI[1*], Agnieszka STACHOWIAK[2]

[1] Instytut Nauk o Zarządzaniu i Jakości, Wydział Ekonomii i Zarządzania, Uniwersytet Zielonogórski; p.niewiadomski@wez.uz.zgora.pl, ORCID: 0000-0002-2805-4671
[2] Instytut Logistyki, Wydział Inżynierii Zarządzania, Politechnika Poznańska; agnieszka.stachowiak@put.poznan.pl, ORCID: 0000-0002-1874-9218
* Correspondence author

Purpose: The belief that there is an economic demand for results of an application nature was the main inspiration to undertake the research, the main goal of which is to develop a set of criteria defining a sustainable product and, on this basis, to prepare a method for its evaluation.
Design / Methodology / Approach: In the theoretical layer, the method of reconstruction and interpretation of the literature on the theory of sustainable production will be used, while in the design layer, a research procedure based on a creative discussion conducted among deliberately selected field experts (competent judges) will be initiated. At the practical level, it is suggested to develop and use a method in the practise of enterprise - assessment of selected parts and technical components of agricultural transport means in terms of defined criteria (characteristics).
Findings research established what criteria a product must meet to be attractive from the manufacturer's point of view, on the one hand (economic criteria) and, on the other hand, to meet the demands resulting from the sustainable development policy (socio-environmental issues). The method developed to evaluate a sustainable product was tested in the practise of companies in the agricultural machinery sector. On this basis, it was estimated to what extent the analysed parts and components of technical means of agricultural transport meet the postulates adopted under the developed method. Thus, the authors present a complex approach and broadly understood assessment and related criteria that predispose a product to be "sustainable".
Research limitations/implications: There are many ambiguities in the interpretation of the concept of a sustainable product. This term has an ambiguous meaning. Defining a sustainable product is as difficult as its precise differentiation in enterprise implementation processes. Despite many attempts to reconcile the positions among researchers, there is no clear agreement on the meaning of this concept. What is a sustainable product and, consequently, what methods should it be tested for? The above issue determined the initiation of directional research aimed at obtaining an answer to this question.
Practical implications: The developed method will influence the adaptation of products to the requirements of a sustainable and resource-efficient circular economy and reduce the amount of waste in the production process. Thanks to the publication, the company has a chance to notice ecological problems much more broadly and, by influencing them, indirectly reduce the

burden on the natural environment. The implementation of the method will result in a change in the approach to ecological problems from the end of the production process to the source of the production process (process design).
Social implications: When choosing a specific product, consumers receive a tool that allows them to define the orientation of the companies that produce it on environmental and social issues. This approach accelerates the process of greening production companies operating in the agricultural machinery sector.
Originality/value: This work presents procedures and tools that allow the identification of key characteristics of a sustainable product and the method of parameterizing them in relation to parts and technical components of agricultural transport means. The developed proprietary profile of sustainable product features is the starting point for improving the assortment database management processes. In the context of the research subject, the developed assessment model can be used to improve the product portfolio of companies in the agricultural machinery sector and related sectors.

Keywords: sustainable product, environment, economics, society, agricultural transport.

Category of the paper: Research paper.

1. Introduction

How is the concept of a sustainable product recognised by representatives of agricultural machinery sector enterprises operating in Poland (production of technical means of agricultural transport)? What criteria (postulates) for assessing a sustainable product should be taken into account when making its overall assessment and how to define a scale estimating each of them?

The above questions and the belief that there is an economic demand for utilitarian results were the main inspiration for undertaking research, the main goal of which is to define a list of criteria for a sustainable product and, on this basis, to prepare a method for its evaluation. Achieving such a goal requires the formulation and implementation of partial goals, which are defined as follows:

- At the theoretical and design level – a literature search on the subject in direct relation to the sustainable product; the authors intend that this will be expressed in a hypothetical set of criteria for assessing the product in terms of features that constitute its sustainability; in the further research procedure, these criteria will be subject to expert assessment;
- On the empirical level, the use of the method in the practise of enterprises from the machinery sector; an assessment of the selected product group will be carried out, taking into account the differentiation criteria.

The theoretical and empirical nature of the publication determines the research methods to be used. In the theoretical layer, the method of reconstruction and interpretation of the literature on sustainable production will be implemented, while in the design layer, a research procedure based on a creative discussion conducted among selected experts, representatives of enterprises

in the sector under research (production of parts and technical components of agricultural transport means), universities (University of Life Sciences) and research and development units (Poznań Institute of Technology).

The purpose of the work is to show a broader perspective on product evaluation in the context of sustainable production; provide practical tips in this regard. The above is determined by the fact that enterprises are increasingly faced with the dilemma of whether to focus on low-cost production (not necessarily taking into account socio-environmental requirements) or whether to reorient their key resources towards highly professional production in the "economy-environment-human" paradigm. What are the advantages and disadvantages of this? What conditions must be met to move towards sustainable production? These and a number of other questions became the basis for the authors to undertake research in the field of sustainable product assessment, especially since there is an obvious need to explore and create theories in the area of "sustainable" forms of organising the production process.

The complexity of the description and quantification of existing conditions in the field of sustainable product assessment makes this issue an important theoretical and practical problem that bothers management staff and business owners, especially those who see the need for change. That is why work aimed at filling the existing knowledge gap is so important. In the context of the above, the authors decided to conduct a series of studies, the subject of which was an attempt to model a product evaluation method using desiderata reflecting its level of sustainability.

2. Literature query

The literature search on the subject has been an inspiration to carry out more business-orientated research and has enabled the confrontation of research conclusions and observations with the published findings of outstanding researchers. Due to the desire to examine the most well-recognised trends and standardise the approach when formulating evaluation criteria, the analysis of Polish and English-language publications was used. The two largest indexing databases (Web of Science and SCOPUS) played a key role in the literature review. However, it was also decided to include scientific texts written in Polish and to reflect specific features of the market. Therefore, the publications catalogued in EBSCO and BazEkon were also included in the final database. The selection of databases was determined by the availability of publications covering the subject of research and their academic quality.

The lists of publications in each base are very broad (over a hundred thousand of papers and books) and multidisciplinary, located in natural sciences, engineering, economy, and business. Since defining characteristics based on the literature is very difficult (individual researchers create broad lists of evaluation criteria, without rankings, using various terms and interpreting

them differently). The authors, based on their knowledge and experience, limited their reading lists to works within management and business areas, available in full-text and corresponding to the research goal. Moreover, it was considered obligatory (taking into account the purpose of the research) to reduce the amount of available information, presenting only key conclusions from the perspective of the research process:

- Maturity in the area of effective product implementation is expressed by the company's ability to effectively select products so that their implementation supports the company's goals and strategy (Jabbour et al., 2015; Susiati et al., 2023; Hapuwatte, Jawahir, 2021; Albino et al., 2009; Munoz-Pascual, 2019; de Jesus Pacheco et al., 2019);
- As the sustainability of the product portfolio increases, the organisation's sustainability increases, and resources are used more effectively (Aibar-Guzman et al., 2022; Melander, 2017; Tao, Yu, 2018);
- A sustainable product is an expression of the commonly held belief that economic efficiency, pro-environmental activities, and human orientation are a guarantee of increasing the efficiency of an enterprise's operations (de Medeiros et al., 2022; Eslami, Krishnan, 2023; Tischner, Charter, 2017; Hernandez, 2019);
- Offering a sustainable product means that the company focusses on features that are key to buyers and consistent with the requirements of the socio-economic environment (Bangsa, Schlegelmilch, 2020; Villamil et al., 2022; Wang, Su, 2022; Song, Sakao, 2017; Saeed et al., 2019);
- Shaping a sustainable product occurs in a reactive model: first, the needs and requirements of the environment are identified, and then a product taking them into account is developed (Li et al., 2021; Howard, Hadfield, 2006; Schulte, Hallstedt, 2017);
- Profit is important and desirable, but it is emphasised that it cannot be treated as the only direction of implementing the development strategy in every situation and at all times (Zhang et al., 2020; Chiu, Chu, 2012);
- When assessing a sustainable product, a number of methodological problems emerge that must be solved (Watkins et al., 2021; Jiang et al., 2021; Schulte, Knuts, 2022; Tischner, Charter, 2017; Chen, 2018; Badurdeen et al., 2018; Mesa et al., 2019);
- Problems with assessing a sustainable product result mainly (but not only) from the fact that we are still dealing with a multitude of various directions, trends, approaches, and definitions that are incompatible with each other (Liu et al., 2020; Hallstedt, Isaksson, 2017; Ocampo et al., 2020).

The difficulties in measuring the factors determining a sustainable product also arise from the fact that individual researchers who create lists of determinants most often rely on descriptions in the literature. There is no reference to practical needs in this regard. According to the authors, diagnosing the evaluation factors selected in this way is too general, artificial, and unclear, not to say, detached from reality, because the evaluation criteria change over time

and should be modified situationally, adequately to the requirements of the socio-economic environment and the market.

3. Research framework

3.1. Sustainable products from the perspective of companies

There are many unclarities in the interpretation of the term "sustainable product". This term has an ambiguous meaning. Defining a sustainable product is as difficult as accurately differentiating it in enterprise implementation processes. Despite many attempts to agree on the perspectives of management researchers and practitioners, there is no clear consensus on the meaning of this concept. What is a sustainable product and, consequently, what methods should it be tested for? The above issue determined the need to carry out directional research aimed at obtaining an answer to the question: How is the concept of a sustainable product understood by representatives of production enterprises in the agricultural machinery sector operating in Poland (production of parts and technical components of agricultural transport means)? The research was carried out during direct creative conversations with deliberately selected experts. The interview was conducted according to the scenario implied by the research needs. The form of a free, led by a researcher, and driven by the research goal conversation was adopted. In relation to the assumptions and concepts presented in the literature and based on the experience gained from their companies, the experts were asked to present their own definition of a sustainable product. Expert discussions were conducted during face-to-face meetings held from 22 to 23 September 2023.

When interviewees were selected, their professional experience was taken into account. In each case, these were professionally active people who actively participated in the implementation processes of technical parts and components of agricultural transport means. The authors' intention was to collect proposals for defining a sustainable product, which in the future gave rise to modelling criteria and an evaluative scale. The discussion of criteria in relation to their hierarchy of importance and interpretation of a sustainable product was the key to further research.

Expert interviews and a detailed search of the literature on the subject indicate that a sustainable product is characterised by:

- medium-term perspective and high probability of achieving significant benefits in the form of profit, taking into account environmental and social standards,
- diversity, which causes them to be classified into different categories,
- income perspective, which is a derivative of potential value (the greater the value of the product for the customer, the greater the chances for sustainable development; however,

full customer orientation requires offering not only products, but a specific value for the market segment),

- cost accounting based on actual, not catalogued standards of labour intensity, applied technologies, and the resulting consumption of raw materials,
- specific expectations regarding the features of products (including quality) offered at given prices (proper response to these expectations encourages most customers to make purchases),
- striving for the highest quality of the product by using available solutions and resources (the relationship between the level of quality and price as well as possible services provided with the product are one of the main factors determining the sustainability of the company),
- maximising the properties of the product ensuring uninterrupted ability to work for the longest possible period of time,
- a bundle of interrelated physical features, usability, and benefits.

Taking the above as an interpretation, this study assumes that a sustainable product consists of physical features and elements that determine the strength of perception of the product by potential buyers, as well as by competitors and suppliers, i.e. in the case of parts and technical components of agricultural transport means, durability, reliability, quality, aesthetics, price, and technical solutions. These elements are assumed to be not permanent categories. Changes or modifications to the components of this level depend primarily on technological progress, evolution of consumption patterns, and socio-environmental norms. This means that the elements accompanying the core of a sustainable product should be a variable combination adapted to the needs, preferences, and requirements of the market, while enabling the product to be distinguished among competitive offers.

Ensuring the quality and durability of the product (through the entire cycle, starting from resource and material acquisition, through its production, processing, transport, storage to purchase by the consumer, and recycling) is a premise that significantly determines a sustainable product. It also implies a relatively high degree of meeting the requirements resulting from market needs, taking into account the latest achievements and experience in the processes of design, construction, production, and operation. Therefore, it influences the level of modernity throughout the product's life cycle, which is important from the perspective of a sustainable product.

A sustainable product is a "relationship-based" product in which the consumer is simultaneously involved in the process of creating and promoting the product. During the research, it was found that customers are the ones who, in a sense, create the value of the product (components and parts) they receive. In this sense, the customer's actions consist of the broadly understood individualisation of the value composition (customisation), i.e., taking actions aimed at obtaining values tailored to their needs and expectations. That is why increasingly efficient and modern production technologies that are neutral (not harmful) to the environment

are so important in the production process of parts and components. New methods of organising production (aimed primarily at eliminating any losses resulting from production processes) significantly define a sustainable product.

In the context of a sustainable product, attention was paid to its compliance with EU directives. In the case of producers of components and parts for agricultural trailers, compliance with the regulations on technical conditions and vehicle equipment (traffic on public roads) and compliance with environmental standards, which are a prerequisite for sustainable production, are crucial.

The above characteristics are the objective opinions, views, and judgments of field experts invited to the research, which constitute the basis for formulating assessment parameters important from the perspective of a sustainable product.

3.2. Research framework

In the ongoing scientific discourse, the view is often expressed that the current level of innovation of Polish enterprises undoubtedly does not match the expectations and ambitions of the global market. According to the authors, this view is completely unjustified, although the Polish industry must make the effort to implement innovative and sustainable products to sustain the opportunity to develop. Undoubtedly, new development perspectives are currently being created in which combining the achievements of various fields of knowledge or searching for an appropriate place for cooperation between enterprises and the research and development sphere is not only possible but also necessary. In the authors' opinion, the basic value and development opportunity of enterprises can and should be openness to interdisciplinary implementation projects. In the context of the above, the authors consider it advisable to search for research topics (using the full potential of the fields of management and quality sciences and engineering and technical sciences) wherever such potential can and should be used.

The starting point of the presented research are the authors' experiences, which illustrate the possibility of adapting the results obtained in interdisciplinary research to the needs of newly identified problems defined in management practise. Nowadays, whenever it is assumed that production will be adjusted to the dynamically changing customer requirements (responsive production), it should be ensured that in each case a product tailored to the customer's needs is created. Therefore, in addition to personalising the final product, the issue of agile reorganisation of production depending on changes in the economic situation of the market is also important. Meeting the challenges related to low-emission production will be an important point on the development roadmap of modern enterprises. It is the responsibility of companies to take appropriate actions to increase the efficiency of creating new products and managing their circulation. Increasing environmental pressure and decreasing natural resources will force the closure of the raw material cycle and the reuse of previously treated resources as waste. This is a serious challenge and requires a number of adjustments in the production area.

This is a big technological challenge for enterprises because the circular economy will need new materials and new methods of product design (eco-design).

The evaluation of a sustainable product and an attempt to base its improvement on this concept requires the development of a set of boundary conditions and assumptions and their appropriate management. Such a concept requires adaptation to the specificity of a specific sector and its representatives. So far, no research work has been carried out to organise and develop in a comprehensive way the issues related to the assessment of sustainable products, especially in the context of companies producing parts and components of technical means of agricultural transport (agricultural machinery sector).

Due to the multidimensionality and diversity of the concept of "sustainable product", assessment is an extremely complex undertaking that requires a holistic approach. It should be emphasised that when defining the basic designations for assessing a sustainable product and determining its level, they cannot be treated solely in the category of barriers and limitations. Individual categories are the foundations ensuring the coherence of the assessment system and defining the level of product adaptation to the requirements of the environment, and not factors limiting the validity of its implementation.

It seems that the complexity of the problems and the little scientific research so far justify treating these issues as important. Based on a literature search on the subject, there is an obvious lack of holistic studies that would comprehensively and completely cover the issues discussed in detail in relation to the indicated sector and at the same time would attempt to identify the cognitive gap (lack of measurement method).

3.3. Research goals, questions, and assumptions

The study conducted research whose main objective was to define a set of criteria to define a sustainable product and, on this basis, to prepare a method for its assessment. Achieving the main goal required the formulation and implementation of theoretical (cognitive), methodological, and practical partial goals (Table 1).

Table 1.
Partial Goals Definition

Goal		Tasks
Theoretical and Cognitive	Producing a catalogue of postulates reflecting a sustainable product (significantly articulated in the literature on the subject)	Literature search on the concept of sustainable production
	Producing a catalogue of postulates reflecting a sustainable product (essentially articulated by selected field experts)	Expert research (brainstorming, crushing method)
Methodical	Specifying the procedure for forming the evaluation method, taking into account key postulates, and the mechanism for determining their hierarchy.	Testing the method among selected competent judges
Practical	Determining the level of achievement of key criteria from the perspective of a sustainable product (assessment methods).	Evaluation of selected parts and technical components of agricultural transport means (object: technological trailer)
	Recommendations and Key Conclusions	

Source: own work.

The research will specify the criteria that the product must meet in order to be attractive from the manufacturer's point of view on the one hand (economic criteria) and, on the other hand, to meet the demands resulting from the sustainable development policy (socio-environmental issues). The method developed to assess a sustainable product will be tested in the practise of enterprises in the agricultural machinery sector. Selected parts and components of technical means of agricultural transport will be assessed. The object of the investigation is a technological trailer (Figure 1).

Figure 1. Research object - Fortschritt technological trailer T-088.

Source: ZPCZ Fortschritt internal documents.

The assessment will verify the possibility of using the method in the practise of enterprises, on the one hand, and, on the other hand, the level of fulfilment of the criteria by selected parts and components (implementation of the postulates adopted within the developed method). Thus, the authors present the complex topic of broadly understood assessment and related criteria that predispose a product to the name "sustainable".

In the context of the conducted analyses, research questions were formulated (Table 2).

Table 2.
Research Questions

No.	Research Questions	Verification Approach
P_1	What requirements described in the literature should be taken into account when formulating a method for assessing a sustainable product?	Literature query + Expert assessment + Verification in Busness Practise
P_2	Do the results of the assessment of technical parts and components of agricultural transport vehicles reflect the defined assessment criteria?	Analysis of selected parts and subassemblies
P_3	Do the tested parts and components meet the criteria to be classified as a sustainable product?	
P_4	What should be the level of implementation of the selected criteria in relation to technical parts and components of agricultural transport means?	Expert Verification

Source: own work.

The belief that there is an economic demand for results of an applied nature, on the one hand, was the main inspiration to carry out the research, and on the other hand, it became the starting point for formulating two assumptions (Table 3).

Table 3.
Research assumptions (presumption)

Assumption 1	The assessment method developed as a result of expert discussion reflects key factors from the perspective of a sustainable product.
Assumption 2	The method of assessing a sustainable product is a compilation of predictors, on the one hand, directly related to the product (e.g. cost, quantity, inputs), and on the other hand, it takes into account elements of the production environment (e.g. ecological and environmental conditions, such as post-production waste and the possibility of its use in another production process) and human resources used in its life cycle process.

Source: own work.

The presented research covers the issues of sustainable products, but it is important that they provide at least a minimum of guidance for those who want to evaluate the product portfolio in their company. It seems that the relatively little scientific recognition and complexity of the problems that occur in business practise justify treating these issues as a subject of research, which is reflected in this publication and the assumptions related to it.

4. Methodology development

To identify and adopt criteria for a sustainable product and define a scale to assess each of them, the knowledge of 11 experts was used as part of the relevant research (Table 4). A creative discussion was held among nine experts directly related to production companies operating in the agricultural machinery sector. When selecting the discussants, their professional experience (9 people) and their research and scientific experience (2 people) were taken into account. In each case, these were people who were actively active professionally participating in the implementation processes of the companies or institutions from which they come or for which they work (Table 4).

Table 4.
Expert Catalogue

<table>
<tr><th>Symbol</th><th>Expert</th><th>Field of expertise</th><th>No.</th><th>Age</th><th>Professional experience</th><th>Enterprise size</th></tr>
<tr><td>B.P., IK, PN, GW, TPP, HK, BH.</td><td>Owners (enterprises in the agricultural machinery sector)</td><td rowspan="3">Organisation and management: developing and implementing strategic goals, including ensuring sustainable growth.</td><td>7</td><td rowspan="4">30-40
2 persons

41-50
6 persons

60 and more
3 persons</td><td rowspan="4">Less than 15 years
1 person

More than 15 years
10 persons</td><td rowspan="4">Small (less than 50 employees)
3 persons

Medium (51-250 employees)
4 persons

Large (more than 250 employees)
4 persons</td></tr>
<tr><td>J.K.</td><td>Product manager</td><td>1</td></tr>
<tr><td>W.B.</td><td>Chairman of the Board</td><td>1</td></tr>
<tr><td>T.W.</td><td>Academic</td><td>Organic cultivation, sustainable and sustainable development, agricultural mechanisation</td><td>1</td></tr>
</table>

Cont. table 4.

K.B.	Researcher (PIT – Łukasiewicz)	Product safety certification declarations of conformity	1			

Source: own work.

During the main session, three key stages were established, the implementation of which determined the achievement of the goals implied by the research, including: (1) formulating tasks to be solved during the session, (2) conducting an idea generation session, and (3) collecting proposals for sustainable assessment criteria. product and defining an evaluative scale for each of them (discussing the criteria in relation to their hierarchy of importance and how to interpret them). It was agreed that each expert has the right to comment on the topic discussed. It was also noted that in addition to presenting your own ideas, it is worth developing and combining the ideas of other participants. The better the group's cooperation, the greater the probability of success. Closing the session, the final assessment of the results was formulated. In the next stage, the research authors wrote down all evaluation criteria mentioned by the interlocutors (they grouped similar ideas) and refined the scale of their evaluation in a given area. This way, the final shape of the evaluation form was established (Table 5). The selected criteria are not permanent categories. The authors are aware that the selection of individual factors is always a matter of convention and depends on the needs of its authors or the institution for which the evaluation sheet is created.

Table 5.
Assessment of sustainable products - description of criteria

No.	Criterion	Scale
K_1	Implementation cost	5 – Implementation does not require large expenditures (preparation of instruments, purchase of specialised production means, acquisition of new knowledge). It is low risk and difficult to imitate. 4 – Implementation requires specific inputs for its implementation. It is low risk and difficult to mimic (entry barriers). 3 – Although the implementation does not require significant outlays, it is burdened with a relatively high risk of the emergence of competitors (entry barriers) and is easy to mimic. 2 – Although implementation requires relatively large expenditures to implement, it is high risk and relatively easy to copy. 1 – Implementation requiring a large scope of research and development work and large financial outlays; relatively high risk; very easy to mimic.
K_2	Return period for invested funds	5 – Immediate return on implementation costs. 4 – Reimbursement of implementation costs within a period of up to 6 months. 3 – Reimbursement of implementation costs in 6 to 12 months. 2 – Reimbursement of implementation costs over a period of 12 to 18 months. 1 – Reimbursement of expenditure incurred on implementation over a period of more than 18 months.
K_3	First Implementation Duration	5 – Average implementation time less than 21 working days. 4 – Average implementation time 22-30 working days. 3 – Average implementation time 31-40 working days. 2 – Average implementation time 41-50 working days. 1 – Average implementation time over 50 working days.

Cont. table 5.

K_4	Efficiency – profit related to cost	5 – Profit is 91-100% of the costs incurred. 4 – Profit is 81-90% of the costs incurred. 3 – Profit is 71-80% of the costs incurred. 2 – Profit is 61-70% of the costs incurred. 1 – Profit is less than 60% of the costs incurred.
K_5	Participation of raw material in the manufacturing process	5 – The share of raw material cost is less than 30% of the total production costs. 4 – The share of raw material costs accounts for 30-39% of the total production costs. 3 – The share of raw material costs accounts for 40-49% of the total production costs. 2 – The share of raw material costs is 50-59% of the total production cost. 1 – The share of raw material costs is above 60% of the total production costs.
K_6	Opportunity of re-production	5 – Delivery at least once a month (cyclical sales). 4 – Quarterly delivery. 3 – Delivery at least twice a year. 2 – Delivery at least once a year. 1 – Delivery at intervals longer than 1 year.
K_7	Single-delivery/ batch size	5 – One-time delivery/production above 500 pieces. 4 – One-time delivery/production of 301 to 400 pieces. 3 – One-time delivery/production of 201 to 300 pieces. 2 – One-time delivery/production of 100 to 200 pieces. 1 – One-time delivery/production less than 200 pieces.
K_8	Environmental Conditions	5 – Completely no harmful impact on the environment. 4 – Limited harm to the environment, although there are some opportunities to improve the production process and product. 3 – Noticeable environmental impact; There are visible opportunities for product improvement. 2 – Significant harm to the environment. 1 – Very harmful to the environment.
K_9	Work environment	5 – Safety is ensured at a very high level and counteracts the burdensome and unfavourable effects of elements of the working space, thus ensuring **ideal working conditions for the operator.** 4 – Safety is ensured at a good level and the burdensome and unfavourable effects of elements of the work space are counteracted, thus ensuring optimal working conditions for the operator. **There is some room for improvement.** 3 – Sufficient safety and prevention of unfavourable and burdensome influences on workspace elements. The operator's working conditions are average. There are visible signs of improvement. 2 – Safety and counteracting burdensome and unfavourable influences of low-level workspace elements. **It only works in theory**; it is not reflected in practise. 1 – Safety and counteracting the burdensome and adverse effects of workspace elements are **practically non-existent.**
K_10	Scope of technological operations	5 – Efficient and modern production technologies that are neutral to the environment (no technological operations emitting pollutants) 3 – Efficient and modern production technologies relatively neutral to the environment (technological operations that emit certain pollutants, e.g., dust (limited ability to counteract pollution). 1 – Production technologies that are not neutral to the environment (technological operations that emit high levels of pollution (low possibility of counteracting pollution).

Cont. table 5.

K_11	Waste generated	5 – The product is characterised by efficiency in the management of raw materials throughout its life cycle. Possibility of using generated waste. The product is designed in such a way that it is recyclable. 3 – The product has limited efficiency in managing raw materials during its life cycle. Limited possibility of using generated waste and recycling. Including technological options in the product development process that allow the harmless disposal of materials that are not subject to reuse. 1 – The product has very low efficiency in managing raw materials during its life cycle. Little possibility of using generated waste and recycling. Limited inclusion in the product development process of technological options that allow harmless disposal of materials that are not subject to reuse.
K_12	Durability, product reliability	5 – The product has the ability to fulfil the intended functions over a long forecast period (over 5 years). 3 – The product has the ability to fulfil the intended functions within the average forecast period (1-5 years). 1 – The product has the ability to fulfil the intended functions within a short forecast period (up to 1 year).
K_13	Type of delivery	5 – Independent, specialised, universal, self-sufficient product (long-term implementation perspective). 4 – Dedicated product; delivery for first assembly (cyclical order guaranteed by an annual contract). 3 – A specialised product tailored to a specific type and technical model of a means of transport (replacement for currently manufactured machines). 2 – A specialised product tailored to a specific type and technical model of a means of transport (replacement for machines no longer produced). 1 – Product delivered once (on special order).
K_14	Safety symbol, standards, directives, and approval	5 – The product complies with the EU directives. Has a risk analysis and risk assessment for the purposes of issuing an EC declaration of conformity **(formally verified product).** 3 – The product complies with EU directives. However, there are no formal tests on hazards and risk assessment for the purposes of issuing an EC declaration of conformity **(the product meets the conditions but has not been formally verified).** 1 – Although the product complies with the specification (value in use), it has not been evaluated in terms of meeting the requirements related to EU directives. Lack of hazard studies and risk assessment (no assessment).
K_15	Flexibility	5 – The client co-creates the values of which he is the recipient; the client's actions involve the broadly understood individualisation of the value composition (customisation). 3 – The manufacturer creates values whose recipient is the customer; the customer's actions involve taking actions aimed at obtaining values tailored to their needs and expectations (customisation). 1 – The manufacturer creates values whose recipient is the customer; the client does not take direct actions aimed at obtaining values tailored to his needs and expectations (customisation).

Source: own work.

Implementation may end with an assessment of varying levels of satisfaction, corresponding to the degree of achievement of a given criterion or the lack of its implementation. In this sense, we are talking about the value of the product, understood as the benefit that the manufacturer can achieve as a result of implementing a sustainable product.

In the proposed evaluation method, to determine the significance of the adopted criterion, an appropriate weight index was assigned (Table 6). It was necessary to obtain reliable information regarding the validity of the criteria. The weights were adopted on the basis of the

authors' knowledge and experience. They fully reflect the opinions expressed by the experts invited to participate in the research.

Table 6.
Criteria and their importance (weight)

No.	Criterion	Weight
K_1	Implementation cost	0,06
K_2	Return period for invested funds	0,05
K_3	First Implementation Duration	0,06
K_4	Efficiency – profit related to cost	0,10
K_5	Participation of raw material in the manufacturing process	0,09
K_6	Opportunity of re-production	0,07
K_7	Single-delivery/ batch size	0,06
K_8	Environmental Conditions	0,07
K_9	Work environment	0,09
K_10	Scope of technological operations	0,05
K_11	Waste generated	0,09
K_12	Durability, product reliability	0,08
K_13	Type of delivery	0,05
K_14	Safety symbol, standards, directives, and approval	0,05
K_15	Flexibility	0,03
Total		**1,00**

Source: Own work.

Evaluation of a product consists of many elements that have a specific value for the manufacturer. The higher this value is from the manufacturer's point of view, the greater the chance of achieving satisfactory results in the form of profit, which, according to the authors, is the basic determinant of the efficiency of using the resources at the manufacturer's disposal. Therefore, profit in relation to the expenditure incurred should be an important criterion for assessing opportunity (weight 0.10). The payback period of the invested funds is equally important (weight 0.05).

In the method modelled for the purposes of this study, based on the points awarded, the following categories of opportunity differentiation were proposed (Table 7).

Table 7.
Product categories - Qualification conditions

Category	Product descriptor	Assessment range	Characteristics	Recommendations
A+	Highly sustainable	4,00-5,00	Every component of the assessment is at the highest level.	Key elements of portfolio; presented and implemented first; attractive from the perspective of the criteria used (long-term perspective)
A	Sustainable	3,00-3,99	Every component of assessment is at a high level; however, there is some space for improvement.	Important elements of portfolio; presented and implemented with available capacity. Perspective product
B	Qualified	2,00-2,99	Components of the assessment are acceptable; however, there is a need for improvement.	Individual approach dependent on the value of a single category.

Cont. table 7.

C	Disqualified	1,00-1,99	Most of the assessment components are at a low level, and do not meet the requirements.	Not important element of a portfolio; not attractive to manufacturers

Source: Own work.

Developing an appropriate product rating category should be one of the organisation's ongoing learning activities. Therefore, the boundary conditions presented in this study are only intended to indicate to companies the direction of such activities, with particular emphasis on the selection of individual differentiation criteria. This will allow the selection of a product of significant value from the point of view of a given company, on the one hand, and, on the other hand, which fits into the globally adopted sustainable development policy. In the future, it may be the basis for formulating assessment tools taking into account detailed criteria for ESG strategies.

5. Methodology implementation – A Case Study

5.1. Characteristics of the assessed object

The subject of the evaluation is the side wall of an agricultural trailer (Figure 2). Based on participant observation, guided interview, market research, and document analysis, the authors obtained the necessary information. The research referred to in this part of the study was made possible thanks to the courtesy of the "Fortschritt" company based in Września (Greater Poland Voivodeship), which produces parts and components intended, among others, for agricultural trailers.

Figure 2. Side wall of an agricultural trailer - subject of assessment.

Source: ZPCZ Fortschritt information materials.

The selection of the part that was evaluated was purposeful. The following part of the study presents the process of assessing a sustainable product from the manufacturer's perspective according to the adopted method. The evaluation was carried out by a five-person team. The experts were: the plant owner, production manager, technologist, and the authors of this study.

5.2. Object assessment

The presented case was a specific qualitative study of organisational and technological phenomena. The authors are aware of the fact that the conducted analyses of individual cases (assessments) are less useful for establishing cause and effect relationships, but they are useful for finding explanatory variables worth considering and suggesting mechanisms by which these variables influence the result or formulation of research questions, which will then be subjected to further analysis due to their value. Taking the above into account, the analysis was carried out with the participation of one of the enterprises. Research results are presented in Table 8.

Table 8.
Assessment results

Nr	Criterion	Weight	Points	Assessment
K_1	Implementation cost	0,06	3	0,18
K_2	Return period for invested funds	0,05	4	0,20
K_3	First Implementation Duration	0,06	5	0,30
K_4	Efficiency – profit related to cost	0,10	3	0,30
K_5	Participation of raw materials in the manufacturing process	0,09	2	0,18
K_6	Opportunity of re-production	0,07	5	0,35
K_7	Single-delivery/ batch size	0,06	1	0,06
K_8	Environmental Conditions	0,07	4	0,28
K_9	Work environment	0,09	5	0,45
K_10	Scope of technological operations	0,05	3	0,15
K_11	Waste generated	0,09	5	0,45
K_12	Durability, product reliability	0,08	5	0,40
K_13	Type of delivery	0,05	5	0,25
K_14	Safety label, standards, directives, and approvals	0,05	3	0,15
K_15	Flexibility	0,03	5	0,15
Total				**3,85**

Source: own work.

As part of the assessment, the indicated product receives 3.85 points, which predisposes it to be called a sustainable product in the context of the adopted criteria. The side wall of the technological trailer, which is the basis for the assessment (Figure 2), should constitute the core of the company's offer, although the possibility of improving the product and the related production process should be considered. The product has a long-term perspective. Although its implementation does not require significant expenditure (implementation costs), it is burdened with a relatively high risk of the emergence of competitors (relatively easy entry barriers). The above translates into the number of 3 points awarded in the *Implementation cost* category. The *return period for invested funds* is relatively short. A period of no longer than 6 months is indicated, which translates into 4 points under this criterion. Detailed analyses have shown that the implementation time of the side wall (due to the technology used) is less than 21 business days (taking into account the first implementation). The above is expressed in five points under the *First implementation duration* category.

Detailed analyses have shown that the profit in relation to the costs of producing the agricultural trailer wall, although relatively high, only indicates 3 points under this criterion. Similarly, *Participation of raw material in manufacturing process* predisposes to awarding only 2 points under the adopted assessment procedure.

The product received a high rating in the *Opportunities of re-production* category - the maximum number of points (5). However, the S*ingle delivery (batch size)*" is so small (less than 200 pieces) that only one point was awarded in the category. Limited harmfulness to the environment means that the product receives 4 points under the *Environmental conditions* criterion. Although there are opportunities to improve the production process and reduce harmful pollutants, it should be noted that this is due to the possibility of using increasingly modern welding methods and the related reduction of welding smoke, which is a mixture of welding gases and dust. Moreover, it was assumed that pollutants resulting from the melting of metals, their evaporation, and oxidation under the influence of the plasma arc, will never be neutral to the environment. The composition of welding dust depends on the welding method and on the welded and auxiliary materials, which should determine the number of points in this stage of assessment. Regardless of what has been said, you should always check whether a given welding station meets environmental protection requirements in this respect. This is related to the next stage of assessment regarding safety and counteracting the burdensome and unfavourable impacts of elements of the workplace. During the investigation, it was found that the manufacturer provides working conditions for the operator at a very high level. Thus, the product receives 5 points in the category *Design of work systems in accordance with the recommendations of conceptual ergonomics*. The product received very high ratings in categories important from the research perspective: *Waste generated*, durability, *product reliability*, *Type of delivery*, and *Flexibility*. As part of the evaluation of individual criteria, the maximum number of points is indicated (5). As for the assessment under the *Safety symbol, standards, directives, and approval* criterion, at a given moment, from the recipient's perspective, it is not necessary to obtain a certificate for this product. However, as for all products traded on the agricultural machinery market, it is a matter of time, because the product delivered to the European market will impose such requirements. Currently, the product receives 3 points under K_14, similarly to the K_10 criterion, i.e., *Scope of technological operations*.

5.3. Conclusions

The research conducted by the authors of the article predisposes them to present important conclusions. The products on the market for agricultural machinery (parts and components of technical means of agricultural transport) are characterised by various parameters (often different) parameters, which, according to the authors, result in different perceptions of their attractiveness from the point of view of a given criterion. The study covered a product that was characteristic in many respects. Therefore, in the future, the study should cover products

different in terms of: (1) use (purchase) of the appropriate type of raw material (sheet, steel bar, ductile casting, etc.), (2) purpose, (3) technological process, (3) price, (4) volume of supplies, (5) type of destination. This is important in the context of defining the assessment parameters and making them more detailed. Therefore, the authors are aware of the fact that the developed concept may raise some doubts (different perception of product evaluation parameters or imperfections in the methodology for assessing product attractiveness), however, the article is intended to constitute a proposal, a starting point (seed) and encourage further research in this direction. and scope. The authors, with full awareness and responsibility, address an appeal to practitioners, manufacturers, because they should also make an effort - develop methodologies and learn appropriate methods of operation - which in the future will certainly be reflected in the preparation of a method for assessing a sustainable product free from defects and shortcomings.

6. Summary

The article presents the author's concept of product assessment in terms of meeting the requirements of sustainable development. The concept was based on literature research and the authors' practical experience. The developed concept was verified by assessing the selected product. The conclusions of the assessment are diagnostic in nature, but the assessment is concluded with recommendations regarding product management and its place in the manufacturer's portfolio.

References

1. Aibar-Guzmán, B., García-Sánchez, I.M., Aibar-Guzmán, C., Hussain, N. (2022). Sustainable product innovation in agri-food industry: Do ownership structure and capital structure matter? *Journal of Innovation & Knowledge*, *7*(1), 100160.
2. Albino, V., Balice, A., Dangelico, R.M. (2009). Environmental strategies and green product development: an overview on sustainability-driven companies. *Business strategy and the environment, 18*(2), 83-96.
3. Badurdeen, F., Aydin, R., Brown, A. (2018). A multiple lifecycle-based approach to sustainable product configuration design. *Journal of cleaner production, 200*, 756-769.
4. Bangsa, A.B., Schlegelmilch, B.B. (2020). Linking sustainable product attributes and consumer decision-making: Insights from a systematic review. *Journal of Cleaner Production, 245*, 118902.

5. Chen, C.W. (2018). Guidance on the conceptual design of sustainable product–service systems. *Sustainability*, *10*(7), 2452.
6. Chiu, M.C., Chu, C.H. (2012). Review of sustainable product design from life cycle perspectives. *International Journal of Precision Engineering and Manufacturing*, *13*, 1259-1272.
7. de Jesus Pacheco, D.A., ten Caten, C.S., Jung, C.F., Sassanelli, C., Terzi, S. (2019). Overcoming barriers towards Sustainable Product-Service Systems in Small and Medium-sized enterprises: State of the art and a novel Decision Matrix. *Journal of Cleaner Production*, *222*, 903-921.
8. de Medeiros, J.F., Garlet, T.B., Ribeiro, J.L.D., Cortimiglia, M.N. (2022). Success factors for environmentally sustainable product innovation: An updated review. *Journal of Cleaner Production*, *345*, 131039.
9. Eslami, H., Krishnan, T. (2023). New sustainable product adoption: The role of economic and social factors. *Energy Policy*, *183*, 113824.
10. Hallstedt, S.I., Isaksson, O. (2017). Material criticality assessment in early phases of sustainable product development. *Journal of Cleaner Production*, *161*, 40-52.
11. Hapuwatte, B.M., Jawahir, I.S. (2021). Closed-loop sustainable product design for circular economy. *Journal of Industrial Ecology*, *25*(6), 1430-1446.
12. Hernandez, R.J. (2019). Sustainable product-service systems and circular economies. *Sustainability*, *11*(19), 5383.
13. Howarth, G., Hadfield, M. (2006). A sustainable product design model. *Materials & design*, *27*(10), 1128-1133.
14. Jabbour, C.J.C., Neto, A.S., Gobbo, J.A. Jr, Ribeiro, M.D.S., De Sousa Jabbour, A.B.L. (2015). Eco-innovations in more sustainable supply chains for a low-carbon economy: A multiple case study of human critical success factors in Brazilian leading companies, *International Journal of Production Economics*, *164*, 245-257.
15. Jiang, P., Dieckmann, E., Han, J., Childs, P.R. (2021). A bibliometric review of sustainable product design. *Energies*, *14*(21), 6867.
16. Li, J., Li, Y., Song, H., Fan, C. (2021). Sustainable value creation from a capability perspective: How to achieve sustainable product design. *Journal of Cleaner Production*, *312*, 127552.
17. Liu, Y., Zhang, Y., Ren, S., Yang, M., Wang, Y., Huisingh, D. (2020). How can smart technologies contribute to sustainable product lifecycle management? *Journal of Cleaner Production*, *249*, 119423.
18. Melander, L. (2017). Achieving sustainable development by collaborating in green product innovation. *Business strategy and the environment*, *26*(8), 1095-1109.
19. Mesa, J.A., Esparragoza, I., Maury, H. (2019). Trends and perspectives of sustainable product design for open architecture products: Facing the circular economy model.

International Journal of Precision Engineering and Manufacturing-Green Technology, *6*, 377-391.

20. Muñoz-Pascual, L., Curado, C., Galende, J. (2019). The triple bottom line on sustainable product innovation performance in SMEs: A mixed methods approach. *Sustainability*, *11*(6), 1689.
21. Ocampo, L.A., Labrador, J.J.T., Jumao-as, A.M.B., Rama, A.M.O. (2020). Integrated multiphase sustainable product design with a hybrid quality function deployment–multi-attribute decision-making (QFD-MADM) framework. *Sustainable Production and Consumption*, *24*, 62-78.
22. Saeed, M.A., Farooq, A., Kersten, W., Ben Abdelaziz, S.I. (2019). Sustainable product purchase: does information about product sustainability on social media affect purchase behavior? *Asian Journal of Sustainability and Social Responsibility*, *4*, 1-18.
23. Schulte, J., Hallstedt, S. (2017). Challenges and preconditions to build capabilities for sustainable product design. In: *DS 87-1 Proceedings of the 21st International Conference on Engineering Design (ICED 17), Vol 1: Resource Sensitive Design, Design Research Applications and Case Studies.* Vancouver, Canada, 21-25.08. 2017 (pp. 001-010).
24. Schulte, J., Knuts, S. (2022). Sustainability impact and effects analysis-A risk management tool for sustainable product development. *Sustainable Production and Consumption*, *30*, 737-751.
25. Song, W., Sakao, T. (2017). A customization-oriented framework for design of sustainable product/service system. *Journal of Cleaner Production*, *140*, 1672-1685.
26. Susiati, D., Aisyah, S., Sentosa, I., Nainggolan, H. (2023). Sustainable Product Innovation as the Main Driver of Business Growth in the Green Economy Era. *West Science Business and Management*, *1*(04), 233-244.
27. Tao, J., Yu, S. (2018). Product life cycle design for sustainable value creation: methods of sustainable product development in the context of high value engineering. *Procedia CIRP*, *69*, 25-30.
28. Tischner, U., Charter, M. (2017). Sustainable product design. In: *Sustainable Solutions* (pp. 118-138). Routledge.
29. Villamil, C., Schulte, J., Hallstedt, S. (2022). Sustainability risk and portfolio management—A strategic scenario method for sustainable product development. *Business strategy and the environment*, *31*(3), 1042-1057.
30. Wang, S., Su, D. (2022). Sustainable product innovation and consumer communication. *Sustainability*, *14*(14), 8395.
31. Watkins, M., Casamayor, J.L., Ramirez, M., Moreno, M., Faludi, J., Pigosso, D.C. (2021). Sustainable product design education: current practice. *She Ji: The Journal of Design, Economics, and Innovation*, *7*(4), 611-637.
32. Zhang, X., Zhang, L., Fung, K.Y., Bakshi, B.R., Ng, K.M. (2020). Sustainable product design: A life-cycle approach. *Chemical Engineering Science*, *217*, 115508.