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ANALYSIS OF COMPANIES' APPROACH TO SUSTAINABLE PRODUCTS DEVELOPMENT: QUALITY, ENVIRONMENT, SOCIETY, COST

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Abstract: Sustainable product development is becoming essential to meet market, but also climate challenges. However, this is problematic mainly because of the need to make many complex decisions at the early stages of product development. Due to limited research in this area, the aim was to analyse the approach of companies to sustainable development when designing new products and improving products already on the market. This approach was considered according to the key aspects of sustainable product development, i.e.: quality (customer satisfaction with use), environment (impact in the life cycle), society (changes in the social environment) and cost. Pilot studies were conducted among manufacturing companies. These were surveys with a Likert scale, in which the following were verified: i) the frequency of actions taken regarding verified aspects, and ii) the degree to which these aspects were taken into account during product development. It was shown, for example, that the most frequently undertaken actions are those related to product costs, then quality, and slightly less often, environment and society. A similar phenomenon was observed in the case of the degree to which these aspects were taken into account in product development activities, which was additionally confirmed by the results of statistical analysis according to the sign test in the STATISTICA program. The results of the pilot studies confirmed the validity of conducting in-depth fundamental studies to determine clear rules and relationships that condition the consideration of key aspects within the framework of sustainable product development.
Keywords: customer requirements, LCA, society, economy, sustainable product development, mechanical engineering

1. INTRODUCTION

The shortage of materials, which has initiated an increase in costs, including the regulations introduced on extended producer responsibility in the European Union, make sustainable development strategies much more attractive to companies (De los Rios and Charnley, 2017; Gilli et al., 2017). Subsequently, the increase in interest in sustainable development makes companies more willing to pay attention to the actions they take. They

should aim at the sustainable use of resources, including key materials, energy, while taking care of market requirements (Alfieri et al., 2018; Carvalho, 2017; Ul-Durar et al., 2023). This procedure helps to improve the quality of products, including limiting negative climate change. As part of effective management in line with sustainable development, it is essential to use efficient technologies, tools, and methods that are based on recovery and reuse (Shapiro et al., 2018; Siva et al., 2016; Tolio et al., 2017; Czerwińska-Lubszczyk et al. 2024, Depczyński, 2024).

According to data cited by (García-Granero et al., 2018), the world's population will exceed 9 million in 2050. This means that in the coming years there will be an increase in demand for products that will generate greater environmental problems, e.g. global warming or excessive waste generation. In this area, manufacturing companies play an important role. Their activities are responsible for the deepening of the aforementioned problems, or, in contrast, they can prevent them by introducing and practising appropriate solutions (Monson, 2023; Pacana and Siwiec, 2022; Song et al., 2020; Vilochani et al., 2024). As part of environmental regulations introduced by governments, including increased awareness of the environmental awareness of customers, companies strive to provide environmentally friendly products (Bigolin et al., 2021; Gajdzik et al., 2024; Hong et al., 2019; Ostasz et al., 2021; Palmero and Montemayor, 2020). Companies modify current products or introduce new products into the market as part of increasing environmental efficiency, but also primarily to adapt to market needs and customer expectations (Adriyanti and Sahroni, 2023; Katsikeas et al., 2016). Other practices include, for example, product and process cost optimisation (Dangelico, 2016; Dekker et al., 2012; Michelly Gonçalves Brandão et al., 2023) and transport (Deja et al., 2021). Sustainable development requires the use of information on product costs, where in this case it refers to a measure of social and environmental impact. As stated by (Świderska and Krysik, 2022), the higher cost of the planet does not directly affect the higher cost for the customer, where the worst environmental impact is cheaper than the equivalent causing less environmental damage. Furthermore, the actions of companies must be undertaken in accordance with corporate social responsibility (CSR) (Maťová et al., 2020, Aastha and Shazi, 2019). This means that they should simultaneously take into account the well-being of customers, environmental aspects, and other interested parties.

Sustainable product development requires the use of appropriate techniques for optimizing production processes, including design of experiments (Dwornicka and Pietraszek, 2018; Jasiewicz et al., 2021) augmented by fuzzy approach (Pietraszek, 2013). This allows the use of special refining techniques (Radek et al., 2020), reduction of fatigue effects (Ulewicz et al., 2014; Markovic et al., 2021) and implementation of appropriate production (Knop et al., 2019) supervision methods. It is also necessary to provide adequate protection against environmental pollution with toxic waste by capturing it in purification processes (Radzymińska-Lenarcik and Ulewicz, 2015; Kalak et al., 2021). However, there are still no clear practices for taking into account key aspects (quality, society, environment, and costs) in activities for sustainable product development. It has been observed that the problem is the need to make many complex decisions at early stages of product development, where it is difficult to predict the correctness of these decisions. This is due, for example, difficult access to reliable data or a lack of tools supporting this process. Furthermore, there is a lack of research on the current approach of companies to aspects of sustainable development. Therefore, the objective was to analyse the approach of companies to sustainable development when designing new

products and improving products already present on the market. These were preliminary studies, the nature and analysis of which are presented in the next part of the study.

2. METHODOLOGY OF RESEARCH

As part of the research, pilot studies were conducted in the form of a survey addressed to manufacturing companies. The survey was developed in an online version using the Google Form Creator (Forms tool). The aim of the survey was to determine the approach of companies to sustainable development when designing new products and improving products already present on the market. The survey was anonymous and took about 5 minutes to complete. When creating the survey, it was assumed that the respondents should understand the aspects of sustainable development as: qualitative, environmental, social responsibility, and financial aspects (Bigolin et al., 2021; Gawlik et al., 2024; Monson, 2023; Pacana et al., 2016; Siwiec and Pacana, 2024). The way they were interpreted was standardised as follows:

- quality aspects - concern the customer's satisfaction with the use of the product;
- environmental aspects - concern the environmental impact of the product throughout its life cycle (LCA);
- social responsibility aspects - concern taking action to bring about positive changes in the social environment;
- cost aspects - concern the total cost of purchasing the final product by the customer.

Manufacturing companies were distinguished according to: size (micro, small, medium, large), scope of activity (local, regional, national, international), implemented system (e.g. ISO 9001, ISO 14001, EMAS, ISO 260000, and others) and industry sector.

Subsequently, two main questions were formed, which at the same time constituted research questions posed as part of the conducted research. The possibility of answering the questions was expressed on a popular five-point Likert scale (Sullivan and Artino, 2013). The first question concerned the frequency of actions taken in the analysed enterprise, where a distinction was made between actions within: a) improving product quality, b) limiting the negative impact of products on the natural environment in their life cycle, c) fulfilling the social responsibility of products, and d) optimising product costs. The method of answering this question was developed in a conventionally adopted time range, which was considered justified on the basis of previous studies, e.g. (Siwiec et al., 2022, 2024), i.e. not at all, less than 1 time / 3 years, 1 time / 2-3 years, 1 time / year, and more often than 1 time / year.

The companies were asked to what extent they take into account the aspects studied when designing new products or improving products already on the market. In this case, respondents could determine the degree of taking into account the aspects on the following scale: 1 – not at all, 2 – occasionally, 3 – often, 4 – very often, and 5 – always (Siwiec et al., 2022, 2024; Sullivan and Artino, 2013).

Pilot studies were conducted in randomly selected companies, the selection of which was characterised by a systematic selection of the research sample. The aim was to initially check the correctness of the developed research questionnaire, including the initial verification of the approaches to sustainable product development in the considered research form. However, as part of the main research, it is planned to expand the research sample according to the principles presented, e.g. in (Hyman and Sierra, 2016; Memon et al., 2020; Siwiec and Pacana, 2021).

Finally, it was checked whether there were statistically significant differences between the analysed variables, i.e. the frequency of actions taken taking into account sustainable development aspects and the degree to which these actions took into account sustainable development aspects. Statistical analysis was carried out in STATISTICA 13.3. with the sign test (nonparametric statistical test), which is used to compare two dependent (correlated) groups in terms of a variable from an ordinal scale. The level of significance was set at $\alpha = 0.05$.

3. RESULTS AND DISCUSSION

The results of the pilot studies cover ten randomly selected manufacturing enterprises from Poland, which were examined in the third quarter of 2024. They were large companies, with an international (80%) and a domestic (20%) reach. The companies examined belonged to the metallurgical (40%), mechanical (20%), aerospace (10%), electrical machinery (10%) and other (10%) industries. Most of them implemented the ISO 9001 system (80%), but also ISO 14001 (20%). The OHSAS 18001 (10%) and IATF 16949 (10%) systems were also recorded.

Initially, the frequency of actions taken in the companies surveyed was analyzed. Respondents determined how often they took actions within the framework of: a) improving the quality of products, b) reducing the negative impact of products on the natural environment in their life cycle, c) fulfilling the social responsibility of products, and d) optimising the costs of products. To present the survey results in a transparent manner, these actions were named after the aspects that characterise them: quality, environment, society, and cost, as shown in Fig. 1.

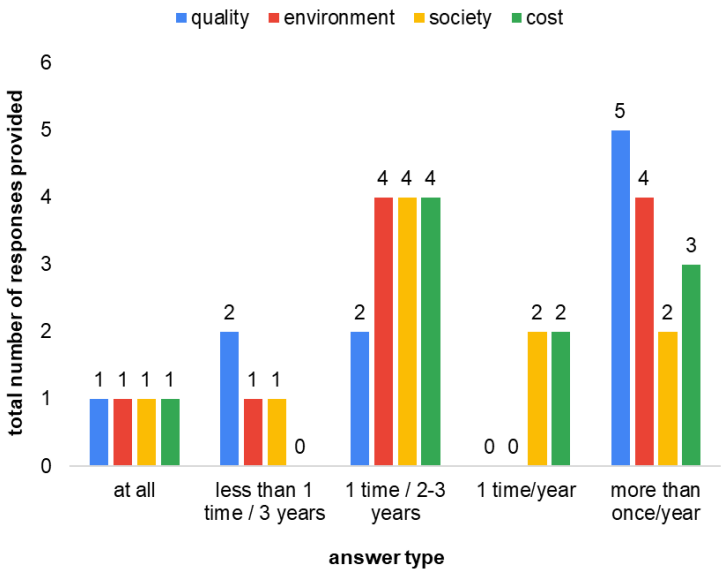

Fig. 1. Frequency of actions undertaken within the framework of sustainable product development in manufacturing enterprises.

Half of the surveyed companies (50%) took action to improve the quality of their products more than once a year. The other half of the companies declared that they take such action once every two to three years (20%) and then less than once every three years (20%). This indicates a relatively high level of participation of companies in meeting customer needs. It was observed that almost half of the companies surveyed (40%) take

action to reduce the negative impact of products on the natural environment during their life cycle at least once a year. The same number of companies (40%) declared that they take such an action once every two to three years. These results indicate that the issue of caring for the natural environment in the form of reducing environmental burdens in the LCA of products is important and is often considered in companies. The results of the pilot studies show that environmental aspects can be considered as important as quality aspects. The frequency of actions taken to meet the social responsibility of the products was analyzed. The largest number of companies (40%) take such actions once every two to three years. Subsequently, the companies indicated that it is once a year (20%) or more often than once a year (20%). Fewer, that is, only 10% of surveyed companies do not take into account the social responsibility aspects of products at all, or do it sporadically, that is, only once every three years. Therefore, actions within the framework of fulfilling the social responsibility of products can be considered less important than actions within the framework of product quality and limiting their negative impact on the environment. The companies surveyed companies in the vast majority (50%) then showed that these place take actions within the framework of optimising product costs, and these actions are taken more often than once a year (30%) or once a year (20%). A significant number of companies (40%) declared taking actions of this type once every two or three years. Therefore, it was confirmed that the cost aspect is very important in the surveyed companies; it can be observed that among the analysed actions, it is the most frequently considered.

As a result, it was concluded that the most frequently undertaken actions are those related to the optimisation of product costs. Subsequently, actions improving product quality and, slightly less frequently but relatively comparable, actions to limit the negative impact of products on the natural environment in their life cycle. The actions that are the least frequently undertaken are actions to fulfil the social responsibility of the products.

The degree to which the aspects studied were taken into account when designing new products or improving products already present on the market was analysed. The results are presented in Fig. 2.

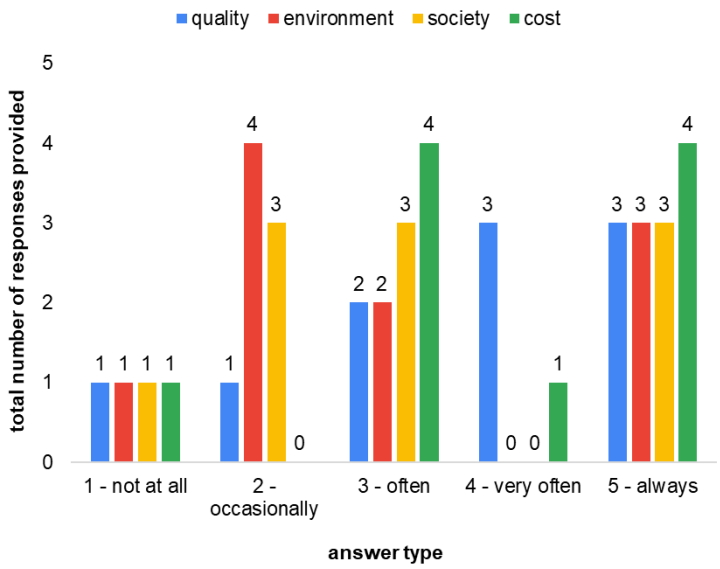

Fig. 2. The degree to which sustainable development aspects are taken into account when designing and improving products in manufacturing companies.

When designing new products or improving products already on the market, differences in the degree of consideration of quality, environmental, social, and cost aspects in the surveyed companies. It was shown that quality aspects (meeting customer requirements) are taken into account to a high degree in the surveyed companies, respectively: 30% always, 30% very often, and 20% often. A high degree of consideration also occurs within the cost aspects, i.e.: 40% always, 10% very often, 40% often. A lower degree of consideration was observed for the social aspect, where in the surveyed companies it is: 30% always, 30% often and 30% occasionally. Similarly, however, a slightly lower degree of consideration occurs for the environmental aspect, i.e. 30% always, 20% often and 40% occasionally. Therefore, it was concluded that when designing new products and improving products already on the market, the highest degree of consideration concerns cost aspects, followed by quality, and a lower degree of consideration concerns social and similarly environmental aspects.

In order to supplement the results of the conducted research, it was checked whether there are statistically significant differences between the analysed variables, i.e. the frequency of actions taken taking into account sustainable development aspects and the degree to which these actions take into account sustainable development aspects. For this purpose, a statistical analysis was carried out in STATISTICA 13.3. Due to the dependent nature of the analysed data groups, including a relatively small research sample, the sign test (nonparametric statistical test) was used. This test is used to compare two dependent (correlated) groups in terms of a variable from an ordinal scale. The level of significance was set at $\alpha = 0.05$. The result is presented in Table 1.

Table 1
Results of the sign test in STATISTICA

Pair of variables	Number of unrelated	Percentage v < V	Z	p-Value
Degree and Frequency	15	66.67	1.033	0.30

Source: Own elaboration based on research results.

It was shown that there are no statistically significant differences (p-Value > 0.05) between the frequency of actions taken taking into account the aspects of sustainable development and the degree to which sustainable development aspects are taken into account in these actions. The results of the statistical test are confirmed in the analysis obtained of individual issues, including the confirmation of the correctness of their interpretations presented.

4. CONCLUSION

Sustainable product development is becoming increasingly popular in current business practices. However, the scope of business activities and their approach to the aforementioned issues is not well known. Therefore, the objective was to analyse the approach of companies to sustainable development when designing new products and improving products already on the market. This approach was considered according to the key aspects of sustainable product development, i.e., quality, environment, society and cost. Pilot studies were conducted among ten manufacturing companies. On the basis of the analysis, the main conclusions were drawn, i.e.,

- manufacturing companies very often undertake activities aimed at meeting customer needs, and quality aspects are taken into account to a high degree when designing new products and improving products already present on the market;
- the issue of caring for the natural environment in the form of reducing environmental burdens in the LCA of products is important and often considered in companies, but is characterised by a lower degree of consideration when designing new products and improving products already present on the market;
- quality and environmental aspects become comparably important in the context of how often they are taken into account when designing new products and improving products already on the market;
- activities related to the implementation of social responsibility of products can be considered less important than activities related to the quality of products and limiting their negative impact on the environment, or cost optimisation, as evidenced by their lower frequency and the degree of their consideration when designing new products and improving products already present on the market;
- activities related to the implementation of social responsibility of products can be considered less important than activities related to the quality of products and limiting their negative impact on the environment, or cost optimisation, as evidenced by their lower frequency and the degree of their consideration when designing new products and improving products already present on the market.

In addition, the statistical analysis carried out confirmed that the indicated frequencies and the degree of taking into account these aspects are consistent and similar within the responses presented by the respondents.

A certain limitation that makes it difficult to interpret the presented results reliably is the small research sample. The results constitute only a pilot test, whose purpose was to initially verify the correctness of the research questionnaire, including ensuring the possibility of improving it before the main research. At the same time, the objective was initially to check the validity of further verification of the approach of companies to sustainable product development.

The results of the pilot studies confirmed the validity of conducting in-depth fundamental studies in order to define clear rules and relationships that condition the consideration of key aspects within the framework of sustainable product development. Furthermore, the form of the survey turned out to be correct and understandable by the respondents.

Therefore, future research will consist of expanding and improving the issues included in the survey studies. It is also planned to deepen the number of surveyed companies as part of the basic research, and then to analyse the obtained results in detail in order to determine the approach of companies to designing and improving products towards their sustainable development.

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