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ASSESSMENT OF INNOVATION AND ENVIRONMENTAL IMPACT OF A MANUFACTURING COMPANY IN THE CONSTRUCTION INDUSTRY

Aleksandra KUMOR-SULERZ

Department of Quality Management and Intellectual Property, Kielce University of Technology;
a.sulerz@tu.kielce.pl, ORCID: 0000-0002-4473-110X

Purpose: The aim of this article is to present an assessment of the innovativeness of a construction company using an original method of diagnosing the state of innovation.
Design/methodology/approach: The work uses an original method for diagnosing the state of innovation and eco-innovation of enterprises, enabling a comprehensive assessment of the level of innovation, identification of the main sources of environmental impact and analysis of the technologies used using the classification of technological readiness levels.
Findings: The company has an average level of innovation, with a clear advantage in terms of technological innovation. Currently, the company is not in the area of sustainable development. The LCA structure has shown that cement is the main source of the company's negative impact on the environment. The TRL (Technology Readiness Level) structure in the company is uneven and includes only level 8-9, which indicates the use of mainly externally acquired technologies. The obtained diagnosis of the company also allows for the indication of proposals for changes aimed at the company's development, which in the future will enable the achievement of sustainable development in terms of innovation and eco-innovation.
Research limitations/implications: In the future, the developed method can be used to conduct research in various industrial sectors, which will allow for the identification of specific challenges and opportunities in the field of innovation and eco-innovation in individual sectors of the economy.
Practical implications: The value of the article results from its practical nature – the developed method can be a support tool for enterprises in the process of planning development strategies, especially in the context of requirements related to ecological transformation and sustainable development.
Social implications: this method can contribute to improving the quality of social life - by supporting more sustainable construction practices, reducing the negative impact on the natural environment and promoting responsible attitudes in business. As a result, this translates into a healthier and safer living environment for current and future generations, thus supporting the goals of long-term socio-economic development.
Originality/value: The novelty presented in the article is the use of an original method of diagnosing the state of innovation and eco-innovation of an enterprise to assess the innovativeness of an enterprise from the construction industry, enabling a comprehensive assessment of not only the level of innovation, but also the identification of sources of environmental impact and the assessment of technologies used using the TRL classification.

It is a response to the existing research gap and can indicate possible directions of beneficial development changes for enterprises.
Keywords: innovations, eco-innovations, LCA, TRL.
Category of the paper: Research paper.

1. Introduction

Innovations, including eco-innovations, play a key role in economic development, contributing to both economic growth and increased competitiveness of countries, regions and enterprises. They can concern various areas of activity, such as: development of new or improved products and processes, implementation of modern technologies, improvements in logistics and distribution, organizational innovations and actions aimed at reducing the consumption of raw materials and energy.

The concept of innovation is interpreted in many ways, both in scientific literature and in business practice. It was first described in more detail by the Austrian economist Joseph A. Schumpeter in his work Theory of Economic Development from 1911. Schumpeter indicated innovations as an important factor of economic development (Schumpeter, 1960). The term "innovation" itself comes from the Latin innovatio, meaning the renewal or introduction of something new (Weir, 1994) According to the OECD and Eurostat definition, an innovation is a new or significantly improved product or process (or their combination) that differs significantly from previous solutions used by a given entity and that has been introduced to the market or implemented in an organization (OECD & Eurostat, 2018). Colloquially, innovation is most often identified with technical changes and understood as research and development activities conducted by economic entities, which result in inventions that are then introduced to the market" (Kalinowski, 2010; Wielewska, 2013).

The concept of eco-innovation was born in the 1990s as a response to the growing importance of innovation in the processes of economic development and the increasing problems related to the degradation of the natural environment. Like the concept of innovation itself, the term "eco-innovation" is multidimensional and is interpreted differently in the scientific literature. One of the first definitions of eco-innovation was proposed by C. Fussler and P. James in 1996. According to them, these are products and processes that not only reduce the negative impact on the environment, but also generate added value for both the company and the consumer (Fussler, James, 1996). Contemporary approaches to eco-innovation emphasize their complex nature and the variety of forms. Kemp and Pearson define eco-innovations as new methods of production, resource management, service provision or organizational activities for a given organization, which – analyzed throughout the entire life cycle of a product or service – contribute to the reduction of raw material consumption, pollutant emissions and negative impact on the environment (Kemp, Pearson, 2008). According to the definition of the European Eco-Innovation Observatory (EIO), eco-innovation is the implementation of a new or significantly improved product, process, organizational change or marketing solution that results in a reduction of the consumption of natural resources and a reduction of harmful substance emissions throughout the product life cycle (EIO, 2013).

The common element of all definitions is the emphasis on achieving environmental benefits while maintaining or increasing the economic efficiency and competitiveness of the organization (Rybaczewska-Błażejowska, 2019; Rybaczewska-Błażejowska et al., 2022).

Assessing the ability of enterprises to implement innovative and eco-innovative solutions is a significant research challenge, mainly due to the ambiguity of these concepts and the diversity of methodological approaches used in research. The literature is dominated by general analyses covering innovations and eco-innovations at the national, regional and sectoral levels (European Commission, 2024). The results of these studies are used, among others, to develop competitiveness rankings that reflect the position of the surveyed entities on the local, national and global market. In-depth analyses of the innovation and eco-innovation of individual enterprises are published much less frequently. Additionally, there is still a noticeable lack of comprehensive methods enabling a comprehensive assessment of the innovation and eco-innovation of enterprises, which indicates the existence of a significant research gap in this area. This type of detailed research is necessary for a precise assessment of the real innovative and eco-innovative activity of enterprises, which plays a key role in their further development and adaptation to changing market conditions (Kaczmarska, 2015; Kumor-Sulerz et al., 2021).

The aim of this article is to present an assessment of the innovativeness of a construction company using an original method of diagnosing the state of innovativeness. This method offers a new perspective on the assessment of innovative activities, also taking into account the impact of products and technological processes on the environment. It is a response to the existing research gap and can indicate possible directions of beneficial development changes for companies.

In connection with the above, the analysis of the innovativeness and eco-innovativeness of a construction company, presented in the next chapter and based on the author's method of diagnosing the state of innovation, is of particular importance. It allows for a comprehensive assessment of the implemented technological solutions, taking into account their impact on the environment and the actions taken to reduce negative ecological effects. The construction industry, despite its traditional specificity, is increasingly becoming a space for the implementation of innovative and eco-innovative solutions (Czajkowska, Ingaldi, 2021, 2023; Kumor-Sulerz, Dziedzic-Jagocka, 2023).

2. Materials and methods

The method of assessing innovation and eco-innovation used in the study belongs to the group of detailed studies focusing on the analysis of individual enterprises. Within this method, innovation was assessed in two main functional areas:

- Technological innovation, including products, machines, devices and applied manufacturing technologies,
- Intellectual innovation, referring to creative, design, research and conceptual activities, the effect of which is the generation of knowledge and intangible resources.

The assessment of innovation is carried out according to a six-point scale (Kaczmarska, 2015, Kaczmarska, Gierulski, 2016). The assessment process also included the methodology of life cycle assessment - LCA (Life Cycle Assessment) and technology readiness level - TRL (Technology Readiness Level), which enabled the development of a detailed environmental profile of the enterprise. Thanks to this, it was possible to determine which elements of the activity - products, processes or other activities - are the main sources of environmental impacts (Rybaczewska-Błażejowska, Sulerz, 2017; Kumor-Sulerz, 2021; Kumor-Sulerz et al., 2021). The result of the study was not only a diagnosis of the current level of innovation of the company, but also an indication of possible directions of development that can contribute to increasing innovation efficiency and reducing the impact on the environment. This approach allows the company not only to better understand its own potential, but also to define strategies that increase its competitiveness and ability to implement innovations. In the conducted study of the company's innovation, various research methods were used, including both theoretical and empirical approaches, including analysis and criticism of the literature on the subject, statistical methods, observations, document analysis, interpretation of data from the studied entity. The basic technique for obtaining information was observation and direct interview with representatives of the management staff, conducted using an original questionnaire. This questionnaire covered issues related to technological and intellectual innovation, eco-innovation, as well as assessment of the level of technological readiness of the solutions used. In the part concerning eco-innovation, the interviews focused on the identification of products and related production processes and their impact on the environment. The collected data covered both input and output aspects of the analyzed processes - including the consumption of raw materials, materials and energy, emission of pollutants into the air, water and soil, as well as the amount of waste generated. In the context of assessing technological readiness, the interviews allowed for determining the company's potential in the field of developing and implementing new technologies - from the concept stage to the full implementation of new products and processes.

3. Case study

The case study presented below aims to comprehensively assess the innovativeness and eco-innovativeness of a company producing paving stones, curbs, edges and garden slabs using the method of diagnosing the state of innovativeness of companies. The company constantly strives to improve its organizational and management processes in order to effectively respond to the growing requirements of its customers. Attention to innovation and product quality means that the company not only maintains a high level of customer satisfaction, but also stands out from the competition. The company regularly monitors changes and new trends in the construction market, which allows it to introduce new solutions and expand its offer with the latest products. Thanks to the close combination of tradition and modernity, the company maintains its position as a leader in the industry in terms of the quality of manufactured products. It has implemented the ISO 9001:2000 Quality Management System, which is a guarantee of the highest standard of products and continuous improvement of production and management processes. Selected high-quality materials are used in production, such as aggregates, cement with increased strength parameters, dyes and other chemical additives obtained from proven suppliers, which ensures the stability and durability of the final products. The selection of materials for production is based on many years of experience and in-depth knowledge of the specifics of the industry. In addition, the company invests in modern production technologies, which allow obtaining products with excellent technical parameters, guaranteeing their longevity and reliability in use. The study was conducted in accordance with the stages presented in Figure 1.

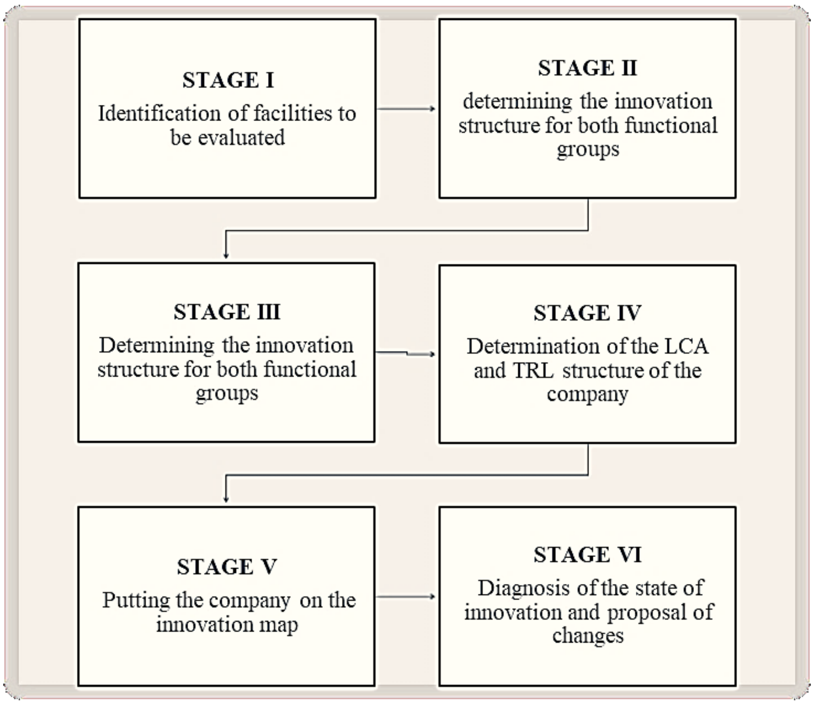

Figure 1. Stages of the methodology for the evaluation of the level of innovation of enterprises.
Source: (Kumor-Sulerz et al., 2021).

Stage 1 – identification of facilities to be evaluated. In the table below 1, the areas important in the conducted study, divided into both functional groups, are specified in the first stage. Technological innovation is activities directly related to products and the production process, including products, machines and devices, applied production techniques, production employees. Intellectual innovation is activities related to creative design, creative thinking, research and development work, i.e. activities that result in intangible products (Kumor-Sulerz, et al., 2021; Kumor-Sulerz, Michta, 2022).

Table 1.
Assessment of enterprise innovation

Enterprise			
Functional group	**Scope of activity**		
	Range	**Evaluated factors**	**Rate**
Technological innovation	Manufactured product	Quality requirements of manufactured products met Traditional materials used in production	$\beta_{5=0,1}$ $\beta_{3=0,1}$
	Manufacturing techniques	Automatic production lines Fulfillment of ecological requirements	$\beta_{5=0,1}$ $\beta_{4=0,1}$
Intellectual innovation	Research and development work	Monitoring the market development of innovative technologies Frequency of introducing innovative technologies	$\alpha_{3=0,1}$ $\alpha_{2=0,1}$
	Organization and management	Participation in fairs Promotion in the media	$\alpha_{4=0,1}$ $\alpha_{3=0,1}$

Source: Own research.

Stage 2 – determining the innovation structure for both functional groups.

In the enterprise, the innovation structure coefficients αi and βi were determined for both functional groups according to formulas (1), (2). The innovation structure of the enterprise is presented in Table 2 and Figure 2.

$$\alpha_i = \frac{u_i}{\sum_{i=1}^{6} u_i} \cdot 100\% \quad (1)$$

$$\beta_i = \frac{v_i}{\sum_{i=1}^{6} v_i} \cdot 100\% \quad (2)$$

where:
u_i – is the number of facilities belonging to the corresponding innovation zone i (i = 1, ..., 6) in the area of intellectual innovation,
v_i – is the number of facilities belonging to the corresponding zone i (i = 1, ..., 6) in the technological innovation area.

Table 2.
Enterprise innovation structure

	Innovation zone	**Structure coefficients *α* of intellectual innovation**		**Structure coefficients *β* technological innovation**	
Conservative (non-innovative)	Definitely	α_1	0,18	β_1	0,00
	Average	α_2	0,18	β_2	0,18
	Moderately	α_3	0,27	β_3	0,45
Innovative	Definitely	α_4	0,18	β_4	0,36
	Average	α_5	0,18	β_5	0,00
	Moderately	α_6	0,00	β_6	0,00

Source: Own research.

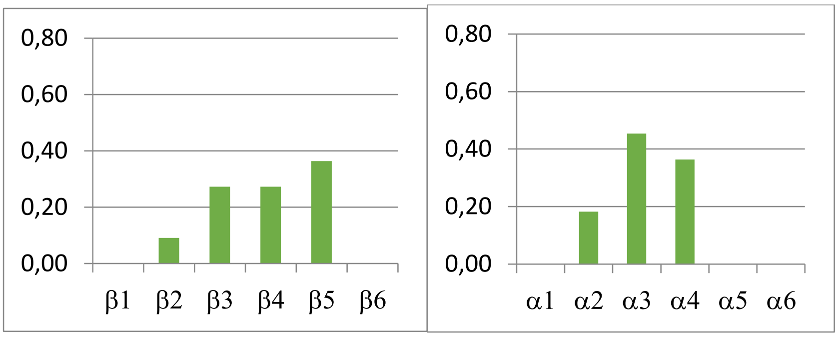

Figure 2. The structure of the company's innovation for both functional groups.

Source: Own research.

Stage 3 – determination of innovation indicators for both functional groups. During this stage, the values of the indicators of the structure of intellectual innovation (α_0) and technological innovation (β_0), are determined, based on which the values of intellectual innovation W_{IK} and technological innovation $W_{IT}$are determined, according to formulas (2) and (3) (Kaczmarska, 2015, Kumor-Sulerz et al., 2021).

$$\alpha_0 = \frac{\sum_{i=1}^{6} i \cdot (i \cdot \alpha_i)}{\sum_{i=1}^{6} (i \cdot \alpha_i)} \quad (3)$$

$$\beta_0 = \frac{\sum_{i=1}^{6} i \cdot (i \cdot \beta_i)}{\sum_{i=1}^{6} (i \cdot \beta_i)} \quad (4)$$

$$W_{IK} = W_I \text{ dla } \mu_0 = \alpha_0 \quad (5)$$

$$W_{IT} = W_I \text{ dla } \mu_0 = \beta_0 \quad (6)$$

$$W_I = 0{,}10 \cdot \mu_0 - 0{,}10 \text{ dla } 1 \leq \mu_0 < 2$$
$$W_I = 0{,}15 \cdot \mu_0 - 0{,}20 \text{ dla } 2 \leq \mu_0 < 3$$
$$W_I = 0{,}50 \cdot \mu_0 - 1{,}25 \text{ dla } 3 \leq \mu_0 \leq 4$$
$$W_I = 0{,}15 \cdot \mu_0 + 0{,}15 \text{ dla } 4 < \mu_0 \leq 5$$
$$W_I = 0{,}10 \cdot \mu_0 + 0{,}40 \text{ dla } 5 < \mu_0 \leq 6$$

In the enterprise, the indicator values are:

$$W_{IT} = 0{,}77 \ W_{IK=} \ 0{,}42$$

Stage 4 – determination of the LCA and TRL structure of the company.

Structure LCA

The aim of the study is to assess the environmental impact of the company in the context of its production activities. The scope of the LCA analysis includes identified products and production processes in the company, including the paving stone production line. The study used a functional unit of 1Mg (megagram) of the final product, which is a reference point for the inventory of input and output data in the production process. This made it possible to determine the environmental impact of each stage of paving stone production in relation to the amount of product produced. In the next stage of the study, the system boundaries were determined, which included all processes related to the production of paving stones. The system boundaries included all phases from the acquisition of raw materials to the production of the finished product. Figure 3 shows the scope of the LCA analysis in the company, illustrating all key processes in the production of paving stones.

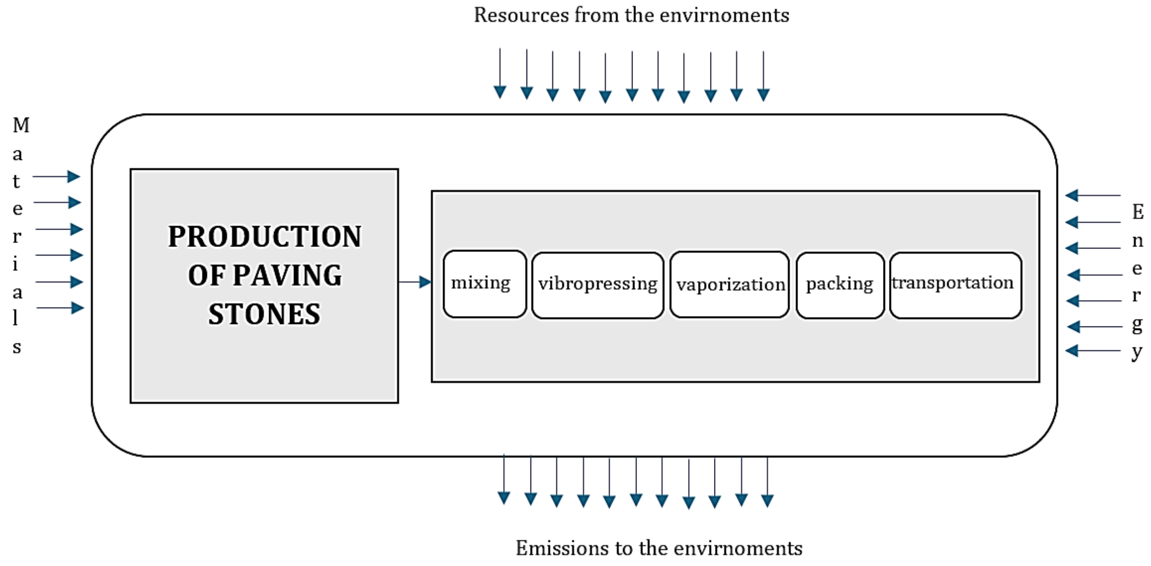

Figure 3. The area of life cycle analysis (LCA) and its basic unit processes.

Source: Own research.

Then, all input and output data related to production were collected. The inputs included materials, stones, water, and the outputs included emissions of pollutants into the air, soil, and water, as well as production waste. Based on the collected data, an environmental balance sheet of the company was created, which included detailed information on the impact of production activities on the environment. This balance sheet included:

- Materials used in the production stones.
- Energy and water consumption.
- Emissions of pollutants into the air, soil, and water.
- Generation of final waste.

The input and output data related to the production of paving stones are presented in Figure 4.

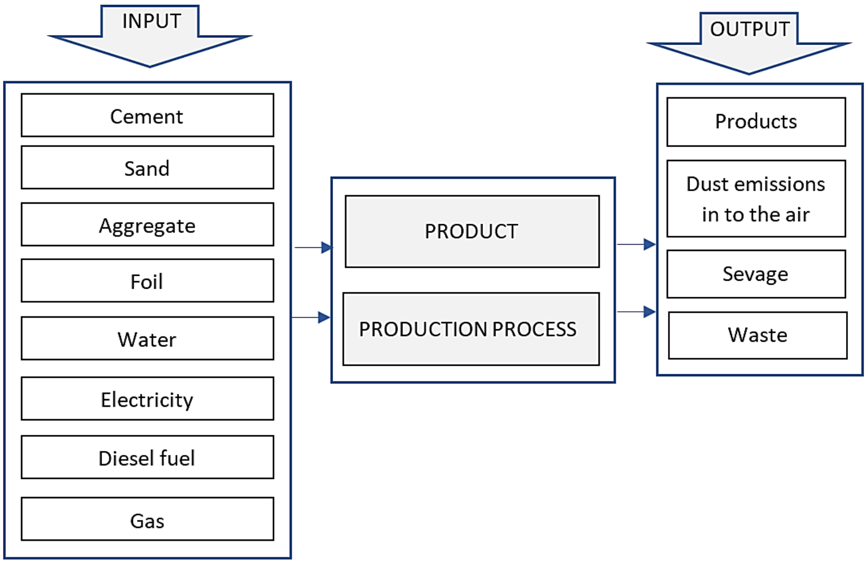

Figure 4. Input and output data related to paving stone production.

Source: Own research.

The LCIA of the company was performed using specialist software Sima Pro 8.1 1 and the ReCiPe Midpoint (H) method included with it. The next stage of the company assessment is to determine the company's environmental profile (LCA structure). This stage includes determining the matrix a_{ij} (MAT_{LCA}), which presents the environmental impact of individual products and production processes of the company (i = 1, …, n), expressed in impact category indicators (j = 1, …, m). The selection of the impact category depends on the selected LCIA method. The matrix recorded in this way (MAT_{LCA}) enables the determination of LCA structure factors α_n within individual impact categories (Kumor-Sulerz et al., 2021). The company's environmental profile in the form of a MAT_{LCA} table takes the form:

$$M_{TRL} = [0{,}0062 \quad 0{,}0001 \quad 0{,}0044 \quad 0{,}0126 \quad 0{,}0014 \quad 0{,}0099 \quad 0{,}0024 \quad 0{,}0041 \quad 0{,}0002 \quad 0{,}0136 \quad 0{,}0165 \quad 0{,}0003 \quad 0{,}0001 \quad 0{,}0006 \quad 0{,}0324 \quad 0{,}0000 \quad 0{,}0008 \quad 0{,}0047]$$

A row in the matrix refers to the product manufactured in the company and its associated production process, i.e. the production process of paving stones. The columns correspond to specific impact categories. According to the ReCiPe Midpoint (H) method, i.e.: climate change, ozone depletion, terrestrial acidification, freshwater eutrophication, marine eutrophication, human toxicity, photochemical oxidant formation, particulate matter formation, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, ionising radiation, agricultural land occupation, urban land occupation, natural land transformation, water depletion, metal depletion, fossil depletion. The LCA structure factors are defined in Table 3.

Table 3.
Enterprise structure coefficients in individual impact categories in the ReCiPe Midpoint (H) method

	Production of paving stones	**Structure factors** $\alpha_i = \sum_{i=1}^{j} \alpha_{n1}$
Climate change	0,0062	0,0062
Ozone depletion	0,0001	0,0001
Terrestrial acidification	0,0044	0,0044
Freshwater eutrophication	0,0126	0,0126
Marine eutrophication	0,0014	0,0014
Human toxicity	0,0099	0,0099
Photochemical oxidant formation	0,0024	0,0024
Particulate matter formation	0,0041	0,0041
Terrestrial ecotoxicity	0,0002	0,0002
Freshwater ecotoxicity	0,0136	0,0136
Marine ecotoxicity	0,0165	0,0165
Ionising radiation	0,0003	0,0003
Agricultural land occupation	0,0001	0,0001
Urban land occupation	0,0006	0,0006
Natural land transformation	0,0324	0,0324
Water depletion	0,0000	0,0000
Metal depletion	0,0008	0,0008
Fossil depletion	0,0047	0,0047

Source: Own research.

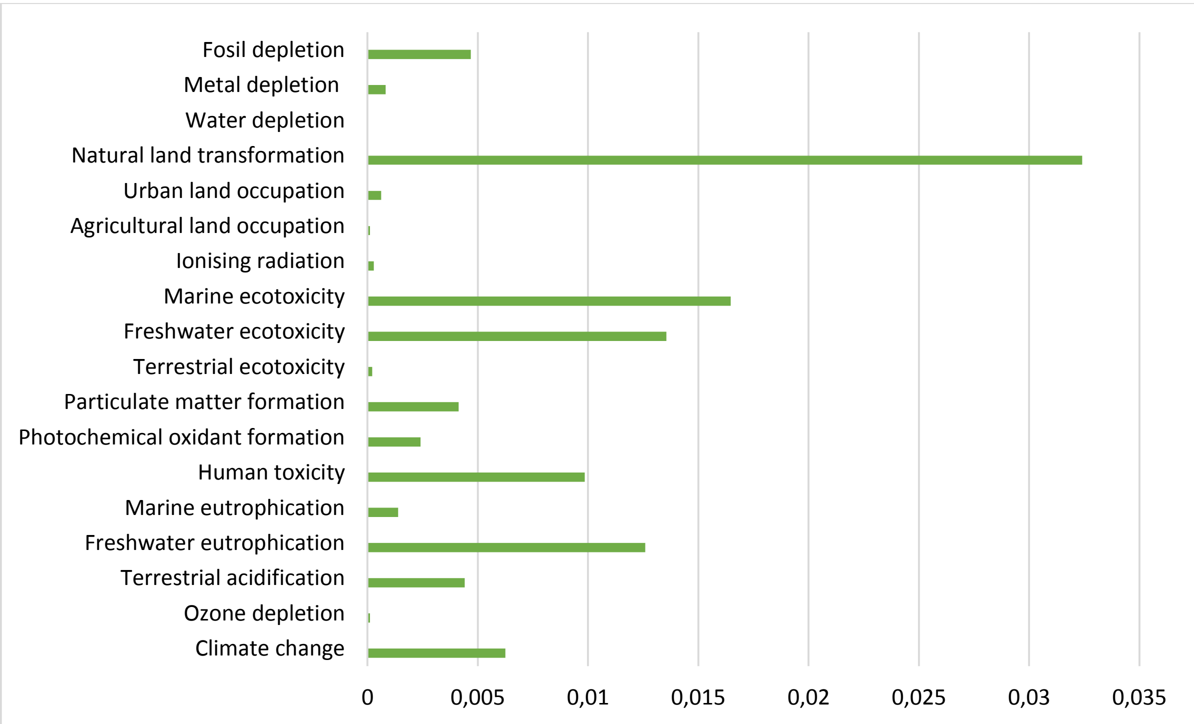

Figure 5. Enterprise LCA structure.

Source: Own research.

The analysis of the LCA structure of the company indicates that it generates the greatest negative impacts on the environment in such impact categories of natural land transformation, marine and freshwater ecotoxicity, and freshwater eutrophication (Fig. 5). The LCA analysis shows that the materials used for the production of paving stones are the primary source of pollution in the company in all key impact categories. For example, cement is responsible for 97.9% of all impacts in the impact category of human toxicity (Fig. 6), and 83.9% of all impacts in the impact category of natural land transformation (Fig. 7).

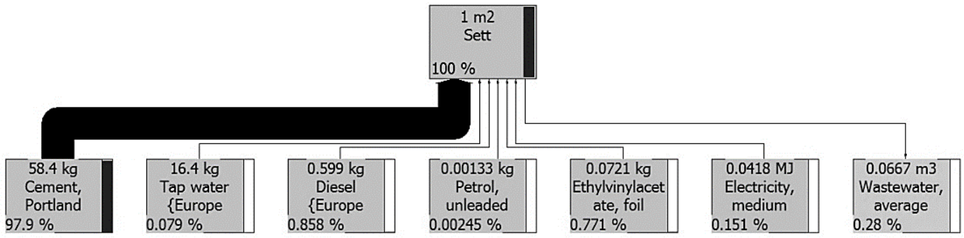

Figure 6. Paving stone production process tree in the category of human toxicity impact.

Source: Own research.

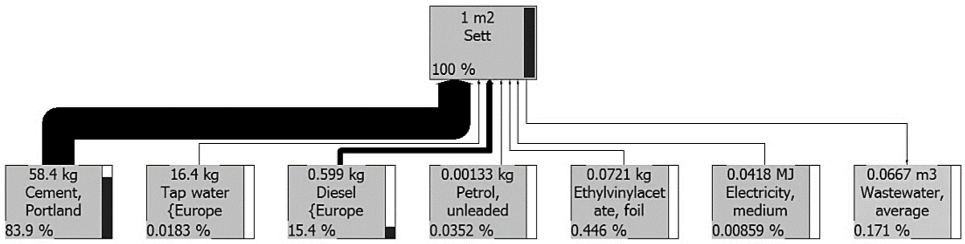

Figure 7. Tree of the paving stone production process in the impact category of natural land transformation.

Source: Own research.

TRL structure

After identifying the technologies used in the enterprise that may be subject to TRL classification, the TRL matrix is determined (M_{TRL}), where the columns correspond to the subsequent levels of technology readiness TRL, while the rows characterize the technologies implemented in the examined enterprise. Two technologies were identified in the enterprise that were subjected to TRL assessment. These technologies correspond to the subsequent rows of the matrix M_{TRL} (Kaczmarska et al., 2015; Kumor-Sulerz et al., 2021).

$$M_{TRL} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$

Table. 4

The state of enterprise technology according to the TRL methodology

Enterprise	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Technology 1	0	0	0	0	0	0	0	1	1
Technology 2	0	0	0	0	0	0	0	1	1

Source: Own research.

Technology 1 – concrete mixing. Producing concrete with the best possible properties is the basis for the production of paving stones. Properly selected ingredients and the use of modern technologies allow for obtaining high-quality products. Aggregates for production are obtained from nearby deposits. In the next stage, multi-grained sand is delivered to a container equipped with a scale, which is mixed with appropriately selected aggregate. Then the mixture is transported to a dumping container located on a rail ramp, which is moved to the inlet of a large mixer. Cement, water and dyes are added to the mixer through nozzles. The ready mixture is transported to a mold in which paving stone patterns are pressed. The work carried out in the company related to this technology is located in the range of TRL level 8-9 with an average degree of complexity. Level 8 – concrete mixing technology was carried out – suggested comments regarding the obtained concrete were taken into account. Level 9 – concrete mixing technology has been tested in operational conditions - with a positive result. The company has been using the described concrete mixing technology to date.

Technology 2 – vibro-pressing of concrete. Concrete is subjected to the vibro-pressing process, which uses a vibrating press of the German brand OMAG with a pressure of 10 tons, which compacts the ready mix. The purpose of concrete compaction is to remove the air inside the mold. This process lasts about 10 seconds, during which the mold is temporarily removed using hydraulic actuators, leaving the formed concrete on the plate. In the next stage, the plates are placed on a special frame and directed to a dryer, where the temperature is 38 C. The work carried out in the company related to this technology is located in the range of 8-9 TRL level with an average degree of complexity. Level 8 – the concrete vibro-pressing process was carried out and the suggested comments regarding the obtained concrete were taken into account. Level 9 – the technology was tested in operating conditions - obtaining a positive result. The company has been using the discussed concrete vibro-pressing technology to this day.

The TRL structure factor calculated according to the formula (7):

$$\vartheta_i = \frac{\sum_{k=1}^{n} a_{ik}}{\sum_{i=1}^{9}\sum_{k=1}^{n} a_{ik}}\text{, for } i = 1 \ldots 9 \tag{7}$$

$$\vartheta_i = 0{,}02$$

The TRL index was calculated according to the formula (8):

$$W_{TRL} = \frac{\sum_{i=1}^{9} i \cdot \vartheta_i}{\sum_{i=1}^{9} \vartheta_i} \tag{8}$$

$$W_{TRL} = 8{,}5$$

The TRL structure of the company is presented in Figure 8.

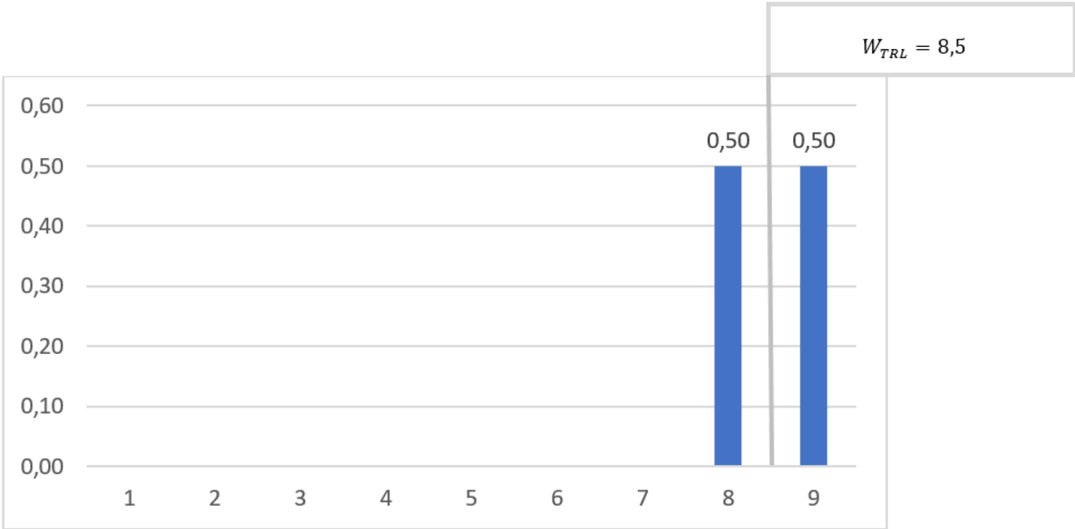

Figure 8. Company TRL structure.

Source: Own research.

Stage 5 – presentation of the company on the innovation map (see Fig. 6). The innovation map is a graphical presentation of indicators W_{IK} i W_{IT} designated for both functional groups. These indicators in the analyzed company are $W_{IT} = 0{,}77$ i $W_{IK} = 0{,}42$, which is shown in Figure 9.

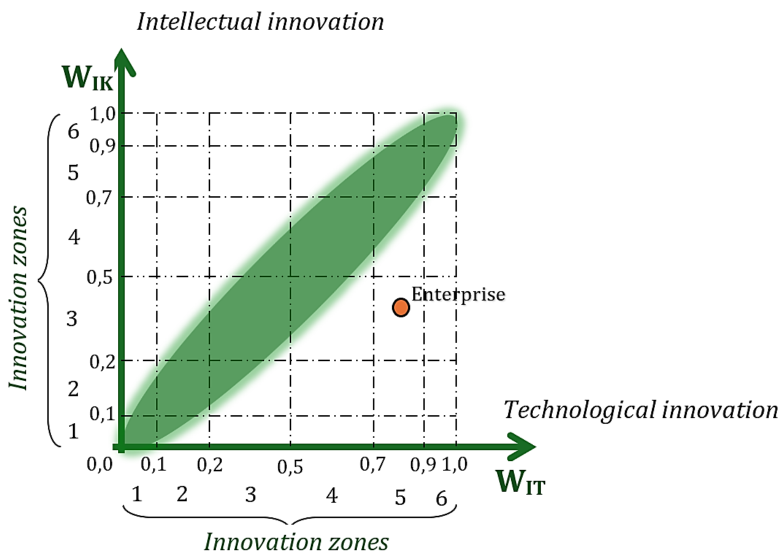

Figure 9. Enterprise Innovation Map.

Source: Own research based on (Kaczmarska, 2015).

Stage 6 – diagnosis of the state of innovation and proposal of changes. The location of the company on the innovation map allows to determine the state of the company's innovation, determines the recommended directions of changes, indicates the areas of activities in which rational decisions regarding improvements should be made and the areas constituting its strengths (Kumor-Sulerz et al., 2021).

The company has an average level of innovation, with a clear advantage in technological innovation. Currently, the company is not in the area of sustainable development. The suggested changes include initiating activities to ensure the development of intellectual innovation.

These activities will create the foundations for achieving sustainable development in the future. A key element in this process will be active cooperation with research and development centers, employee training or employment of highly qualified staff. Such activities will enable the company to create its own innovative technologies and implement them in production. The company's analysis conducted using the LCA method showed that products are the main source of negative impact on the environment, especially in categories such as transformation of natural areas, ecotoxicity (both marine and freshwater) and eutrophication of freshwater. The greatest environmental damage results from the use of cement in the production of paving stones. In order to reduce this impact, the company should focus on implementing eco-innovations in the area of products, including by reducing the consumption of materials such as cement and increasing the durability and strength of the raw materials used. At the material level, we can point to the use of alternative cement binders, such as geopolymers or fly ash, as well as the use of recycled materials and renewable and bio-inspired materials, such as industrial hemp or mycelium (mycelium). Such approaches help reduce the carbon footprint and reduce the impact on the natural environment. In the context of design processes, it would be important to take into account modern digital optimization methods, such as Building Information Modeling (BIM), generative design, or 3D printing using low-emission materials. At the same time, it is worth promoting design strategies based on modularity and the possibility of disassembling and reusing components, which favors the implementation of the principles of the circular economy. At the system level, references to design based on life cycle analysis (LCA), the implementation of circular economy assumptions and the use of environmental certifications, such as LEED or BREEAM, which are important tools supporting the strategy of sustainable development in construction, are important. At the material level, we can point to the use of alternative cement binders, such as geopolymers or fly ash, as well as the use of recycled materials and renewable and bio-inspired materials, such as industrial hemp or mycelium (mycelium). Such approaches help reduce the carbon footprint and reduce the impact on the natural environment. The structure of TRL (Technology Readiness Level) in the company is uneven and covers only the 8th-9th level, which indicates the use of mainly technologies acquired from outside. The W_{TRL} = 8.50 indicator is in the second part of the W_{TRL}< 4.5 range, which indicates limited research and development activity. In order to increase innovation capabilities, the company should focus on the development of research and development works and independent creation of new technologies. Active cooperation with research and development centers and the development of employee competences will allow for independence from technologies acquired from outside, as well as the creation of a strong R&D department. Hiring highly qualified employees would allow for the adaptation and development of technology in accordance with the company's needs, instead of relying solely on the purchase and implementation of ready-made solutions.

4. Conclusion

The article presents an assessment of the level of innovation and eco-innovation of a manufacturing company operating in the construction industry, using an original method of diagnosing the state of innovation. The innovative contribution of this article is the application of an original method for diagnosing innovativeness and eco-innovativeness of enterprises, which was used in the case study of a company from the construction sector. The advantage of the proposed approach is its comprehensiveness – it allows not only for the assessment of the general level of innovativeness, but also for the identification of the main areas of environmental impact and the assessment of applied technological solutions using the TRL (Technology Readiness Level) classification. The method of assessing innovation and eco-innovation used in the study is classified as a detailed study that focuses on the analysis of individual companies.

This method enabled a comprehensive analysis of the company through:

- assessment of the level of innovation and eco-innovation,
- identification of sources of environmental impact (product, production process),
- assessment of applied technologies according to the TRL (Technology Readiness Level) classification.

The company has an average level of innovation, with a clear advantage in terms of technological innovation. Currently, the company is not in the area of sustainable development. The LCA structure has shown that cement is the main source of the company's negative impact on the environment. The TRL (Technology Readiness Level) structure in the company is uneven and covers only level 8-9, which indicates the use of mainly externally acquired technologies. The obtained diagnosis of the company also allows for the indication of proposals for changes aimed at the development of the company, which in the future will enable the achievement of sustainable development in the aspect of innovation and eco-innovation. This method addresses a significant research gap regarding practical tools supporting the transformation of enterprises towards sustainable development. It can provide valuable support in the strategic planning process, indicating possible directions of changes at both the operational and technological level. At the same time, its application in a broader industry context requires further validation and adaptation to the specifics of individual sectors of the economy.

The method proposed in this paper contributes to the literature by combining the concepts of TRL and LCA, which allows for a comprehensive assessment of innovation and its impact on the environment. Thus, the interdisciplinary research framework linking technology management, ecology and sustainable development is strengthened.

The company's diagnosis reveals that although the company demonstrates an average level of innovation, it requires further improvement, especially in the context of the significant impact of cement production on the environment. The uneven structure of TRL levels, with the dominance of externally acquired technologies, indicates the need to invest in the development of own innovations and strengthen technological competences.

In practice, the method is a useful tool supporting companies in identifying weak points and development priorities, enabling planning of activities aimed at increasing innovation and achieving sustainable development goals. The proposed solutions, based on the diagnosis, can help the company reduce the negative impact on the environment, among others by searching for alternative materials or production technologies. The method can also act as a decision-making support in the field of innovation management and ecological transformation, which is particularly important in industries with a high environmental impact, such as construction.

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