Pricing Model For Eco-Innovative Products On The Basis Of Its Technological Readiness

Vasyl Kozyk¹, Oleksandra Mrykhina², Iryna Fadyeyeva³, Lidiya Lisovska⁴*, Ihor Novakivskyi⁵ and Iryna Zinchuk⁶

¹Professor, Lviv Polytechnic National University, Lviv, Ukraine
²Professor, Lviv Polytechnic National University, Lviv, Ukraine
³Professor, Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine
⁴Assoc. Professor, Lviv Polytechnic National University, Lviv, Ukraine
⁵Professor, Lviv Polytechnic National University, Lviv, Ukraine
⁶Teacher, Lviv Polytechnic National University, Lviv, Ukraine

*Corresponding author: lida_lisovska@ukr.net

Abstract. A pricing model for eco-innovative products has been developed based on its technological readiness for commercialization in the context of sustainable economic development. It is proved that the pricing model for eco-innovative products can be based on an integral indicator that includes a set of factors influencing the level of its technological readiness – from the point of view of the developer (manufacturer, seller) and market perception (buyer, consumer, etc.). The formalization of such an indicator is carried out on the basis of algorithms of fuzzy set theory. The developed method is tested on a number of types of eco-innovative products developed by Ukrainian business entities. The obtained price integral indicators are determined by a fuzzy number with a certain range, which makes it possible to take into account the features characteristic of a particular market situation due to the level of technological readiness of eco-innovative products. This method allows you to achieve a higher level of price accuracy.

1. Introduction

Global greening against the background of digitalization and the achievements of the IV Industrial Revolution shows the need for scientists and practitioners to reconsider approaches to developing strategies for managing innovative products of economic entities, taking into account the level of its environmental friendliness. The importance of assessing the environmental component of innovative developments is also indicated by the sustainable development goals of countries, which cover almost all types of economic activity and serve as the basis for developing a strategic vision for the development of the country's innovation process.

Ensuring sustainable development through effective management of environmental innovations is actualized by many modern environmental problems caused by the negative technogenic and socio-economic consequences of industrial progress. An important element of this issue is the methodological support for the transfer and commercialization of eco-innovation, the principles, of which are pricing, which depends on the level of readiness of eco-innovation for commercialization. It is important to distinguish between the types of readiness of eco-innovative products – environmental,
technological, marketing, patent, ability to withstand various types of risks, and so on. Since pricing for eco-innovative products should primarily be based on factors that determine their technological readiness. Based on this, the determining factors of pricing for eco-innovative products will be the levels of their technological readiness. Changes in the level of added value generated by such products will depend on staying at a particular level of technological readiness. In turn, the level of value added will determine the price of eco-innovative products and scenarios for their transfer and commercialization.

So, the actual scientific and practical task is to develop a pricing model for eco-innovative products that would take into account the levels of their technological readiness and the nature of the market environment, based on the principles of ensuring the sustainable development goals.

2. Review of Literature
In recent years, the problem of evaluating eco-innovative products has become popular. This is primarily due to the generation of innovations with a high level of environmental friendliness, due to the growth of human eco-awareness. Problems of eco-innovative products in the context of sustainable economic development were considered by scientists in [1, 2], from the standpoint of life cycle assessment – in the works [3, 4], eco-innovation strategic models were considered by scientists in [5-7], evaluating of eco-innovative products using fuzzy set theory are in [8, 9].

At the same time, the problem of pricing for eco-innovative products is not given due attention in the modern works of scientists and practitioners. Existing methodological developments do not meet market demands. In particular, this issue is not considered in the context of the levels of readiness of eco-innovative products for commercialization. It is advisable to develop a pricing model that would allow us to solve the outlined range of problems. The model should be based on factors influencing changes in the level of environmental friendliness of innovative products and take into account the features of the modern market environment, be maneuverable in reformatting environmental friendliness parameters in the model, and so on.

3. Purpose
The purpose of this research is to develop a pricing model for eco-innovative products on the basis of its technological readiness for commercialization in terms of sustainable economic development.

4. Methodology and Hypotheses
To achieve this goal, it is proposed to use algorithms of fuzzy set theory. This theory is designed to formalize the dependencies of various types of indicators. Methods of fuzzy set theory gained popularity in economic application in the second half of the twentieth century. Among them, one of the most promising approaches to modeling and forecasting economic processes is the fuzzy logic approach.

Our scientific search has shown that the pricing model for eco-innovative products can be based on an integral indicator, which will include a set of factors of influence on the level of its technological readiness. Formalization of such an indicator is possible, in particular, based on the use of algorithms in fuzzy set theory.

To achieve this goal hypotheses are formed:

hypothesis 1: pricing model for eco-innovative products, developed on the basis of algorithms of fuzzy set theory, will allow to formalize and integrate a set of heterogeneous features that determine the technological readiness of this product;

hypothesis 2: the pricing model for eco-innovative products can be effectively used for forecasting in the long run;

hypothesis 3: the pricing model is suitable for eco-innovative products of any level of complexity and any sphere of economic activity.

5. The Results
The pricing model for eco-innovative products should take into account the levels of their technological readiness, which will determine the consumer value of such products and their compliance with the market environment, the development of which is based on sustainable development goals.

In recent years, it has become increasingly difficult to find market analogues for innovative products in order to compare and form the desired competitive price, especially when it comes to eco-innovation. At the same time, the level of innovation in developments is becoming higher and higher. The complexity of pricing for such products is also aggravated by the fact that methodological support for it should be a subsystem in the innovation management system of a business entity. In other words, it should take into account not only the nature of the product itself and the changes caused by it in the external and internal environment of the enterprise, but also factors of influence on it from other subsystems of the enterprise (personnel, marketing, etc.), which are mainly not involved in traditional approaches to pricing.

The pricing model for eco-innovative products should, on the one hand, take into account its environmental value characteristics, which can be determined by the level of readiness. On the other hand, such an approach should include an assessment of the possible behavior of eco-innovative products in the market, including the market effects that they can cause. This also includes the specifics of its implementation (development) by the consumer and the projected competitiveness.

It is proposed to consider the problems of methodological support of pricing for eco-innovative products in the context of two features: the readiness of eco-innovative products from the point of view of the developer (seller) and its readiness from the point of view of market perception (buyer, consumer), on the basis of which to develop an author's pricing model. A task has been created for this purpose:

1) form stages of assessing the technological readiness of eco-innovative products from the point of view of the developer (manufacturer, seller);
2) form stages of assessing the technological readiness of eco-innovative products from the point of view of market perception (buyer, consumer, etc.);
3) substantiate an economic and mathematical method for evaluating eco-innovative products in order to form a pricing model for them.

The analysis of existing methodological approaches to assessing the level of readiness of innovations is carried out (in particular, proposed by NASA, Oslo, etc.) made it possible to identify from them those that may be suitable for the purposes of pricing for eco-innovations for the purpose of commercialization. A number of stages have been added to them, compiled on the basis of practical research. The results are summarized in Table 1.

By their nature, signs containing stages are indicated in Table 1, are quite heterogeneous, with a complex level of mutual correlation, have a mutually mediated impact on the price of eco-innovative products. In order to develop a pricing model for eco-innovative products, it is advisable to use an economic and mathematical apparatus that would be based not only on quantitative methods (which do not always make it possible to take into account changing market conditions), but also take into account qualitative assessments of such products. In this case, it is necessary to integrate the estimates obtained at the stages of assessing the readiness of eco-innovative products into the indicator, which will allow you to adjust the base price previously formed according to the cost assessment approach.

In economics, within the framework of fuzzy set theory, Tzukamoto, Mamdani and other models are popular. Economic assessment of eco-innovative developments based on fuzzy set theory operates with both quantitative and qualitative characteristics. The criterion for the effectiveness of evaluating eco-innovative products within the framework of fuzzy set theory is determined by maximizing the degree of suitability of the obtained estimates for the market situation (commercialization).

The methodology for evaluating phenomena based on fuzzy set theory algorithms is based on a number of theoretical prerequisites, in particular those described by Zadeh L. (1976), which we have developed for the situation with innovative products [8, 10]:

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Table 1. Signs and stages of assessing the technological readiness of eco-innovative products for commercialization

| Signs of evaluation of eco-innovative products | Stages of technological readiness of innovative products |
|-----------------------------------------------|-------------------------------------------------------|
| Readiness of eco-innovative products from the position of the developer (manufacturer, seller) | 1 - study of ecological need of the market, substantiation of the decision on expediency and possibility of satisfaction of this need by ecoinnovative production |
|                                                | 2 - implementation of research and development work on innovative products, in particular in terms of its environmental friendliness |
|                                                | 3 - development of eco-innovative products |
|                                                | 4 - production of a prototype of eco-innovative products; protection of the object of intellectual property rights of eco-innovative products |
|                                                | 5 - certification of eco-innovative products |
| Readiness of eco-innovative products from the market position (buyer, consumer) | 1 - evaluation of attributes of consumer value of eco-innovative products |
|                                                | 2 - assessment of competitive positions of eco-innovative products |
|                                                | 3 - substantiation of information and communication and marketing channels for the market pot of eco-innovative products |
|                                                | 4 - assessment of all types of risks related to the transfer and commercialization of eco-innovative products |
|                                                | 5 - the ability to generate eco-innovative products market effects (convergence, diffusion, spillover, etc.) |

Source: developed by the authors

an object can acquire a state that belongs to a finite set of states \( S \), where there are two disjoint subsets \( S_1 \bigcup S_2 \), where \( S_1 \) is a subset of states that are consistent with the characteristics of the desired state in terms of feature development; \( S_2 \) is a subset of states that are not consistent with the characteristics of the desired (standard or reference) state in terms of feature development. The subset \( S_1 = \{S_{i1}, i = 1, n\} \) contains state types that allow you to function and evolve. Subset \( S_2 = \{S_{i2}, i = 1, m\} \) contains types of states that respond to such changes in parameters or structural relationships that contribute to deviations from the desired result (this will mean that the object is in the process of transition from the \( S_k \) state to the \( S_l \) state, but the operating conditions may not be violated if \( S_k \) and \( S_l \) belong to the subset of \( S_1 \) states);

estimation of the real state of an object is based on analysis of a set \( S \) or subsets \( S_1 \) and \( S_2 \).

The assessment is based on the positions of analysts and methods of its implementation. The model for evaluating innovative products and technologies is expressed as a function:

\[
S = f (\text{Readiness of innovative products from the point of view of the developer}; \text{readiness of innovative products from the point of view of the market (buyer, consumer)})
\]

which is a system of functions of the following order that characterize the stages of technological readiness of eco-innovative products (see Table. 1).

Evaluation of innovative products based on the application of fuzzy set theory algorithms is divided into stages: phasification and formation of a database of fuzzy description rules; development of fuzzy rules; dephasification. Consider the dependence of the price of eco-innovative products on the signs of their technological readiness (Table. 1) using the Mamdani model, whose rules contain fuzzy values (membership functions) in sequences. For this purpose, the stages of readiness of eco-innovative products for commercialization are assigned the value of linguistic terms for adjusting the price of products (Table 2).
Table 2. Signs and stages of assessing the readiness of eco-innovative products and their linguistic terms for use in the Mamdani model

| Signs of evaluation of eco-innovative products | Stages of readiness of eco-innovative products (description of the stages-Table. 1) - linguistic terms of signs | Meaning and explanation of linguistic terms of readiness stages |
|-----------------------------------------------|---------------------------------------------------------------------------------------------------|-------------------------------------------------------------|
| Readiness of eco-innovative products from the position of the developer (manufacturer, seller) – I | Stage 1 – LL (The lowest level) | Lowest level (-50 ... -36%) |
| | Stage 2 – BAL (Below average level) | Below average (-35 ... -21%) |
| | Stage 3 – AL (Average level) | Average level (-20 ... 20%) |
| | Stage 4 – AAL (Above average level) | Above average (21 ... 35%) |
| | Stage 5 – HL (The highest level) | Highest level (36 ... 50%) |
| Readiness of eco-innovative products from the market position (buyer, consumer) – II | Stage 1 – LL (The lowest level) | Lowest level (-50 ... -36%) |
| | Stage 2 – BAL (Below average level) | Below average (-35 ... -21%) |
| | Stage 3 – AL (Average level) | Average level (-20 ... 20%) |
| | Stage 4 – AAL (Above average level) | Above average (21 ... 35%) |
| | Stage 5 – HL (The highest level) | Highest level (36 ... 50%) |

Source: developed by the authors

Using the Mamdani model algorithm in the Fuzzy Logic toolbox component of the MATLAB software package, a set of ratios of expert assessment options with the value of the price integral indicator is formed. In this case, the triangular function of distribution of input feature values (trimf) is selected. A fragment of the rule base introduced into the Mamdani model is shown in Fig. 1.

Fig: 1 Knowledge base for forming an adjustment indicator for pricing of innovative products according to the algorithm Mamdani in the component Fuzzy Logic Toolbox MATLAB (fragment)

Visualization of a fuzzy model of price integrated indicator formation for pricing of eco-innovative products, which reflects the ratio of influences of signs of its readiness for commercialization, given in Fig. 2.
Fig: 2 Reference surface of the system the ratio of the influence of signs of technological readiness of eco-innovative products for commercialization

Within the described system, the resulting surface is a reference. Dephasification was performed using the centroid method.

The developed method is tested on a number of types of eco-innovative products developed by Ukrainian business entities. Programming in the Fuzzy Logic toolbox component and dephasification allowed us to get price integral indicators. An example of this definition is shown in Fig. 3-5.

Fig: 3 Results of determining the price integral indicator for pricing on DC servo conversion device
The obtained price integral indicators are determined by a fuzzy number with a certain range, which makes it possible to take into account the features characteristic of a particular market situation due to the level of technological readiness of eco-innovative products. This method allows you to achieve a higher level of price accuracy. The results of calculations based on the example of a number of types of eco-innovative products are summarized in Table 3.

Interpretation of the obtained results showed that the price of the device (1) previously set by the appraisers (according to Table 2) is 67.45 thousand UAH. This device is characterized by a high rate of readiness from the position of the developer (H – 23.8), due to the significant level of environmental friendliness of components, as well as a high rate of readiness from the market position (buyer, consumer) (H – 40.3). The corrective price indicator for this device is 28.0%. Thus, the price for it can be increased to 86.34 thousand UAH. In this case, the price of the analyzed device is lower
than the average market price – 91.56 thousand UAH. That is, it is possible to increase the current price for the device (1), for example, to the proposed level of 86.34 thousand UAH, because the technology is successfully perceived by the market and has a high level of consumer value, which provides it with competitive advantages. Accordingly, the company will have a higher level of profitability. Further price increases, for example, to the level of the average market, should be studied based on demand elasticity.

| №   | Names of eco-innovative products | Product price, thou UAH / unit | The value of linguistic terms of the factor influencing the price of eco-innovative products | Adjustment indicator (according to the model Mamdani), % | Adjusted product price, thou UAH / unit | Average market price of products, thou UAH / unit |
|-----|---------------------------------|--------------------------------|-----------------------------------------------|-------------------------------------------------------|----------------------------------------|-----------------------------------------------|
| 1   | DC servo conversion device OSL technology IP dosimetry Smooth start device (SSB) | 67.45 32.71 47.57 | H (23.8) AL (-11.3) AL (-9.05) H (40.3) AAL (30.1) BAL (-21.2) | +28.0 +12.7 -1.15 | 86.34 36.86 46.85 | 91.56 40.60 45.5 |

Source: developed by the authors

The described situation is also typical for technology (2). Since, for technology (3), the current price of 47.57 thousand UAH should be reduced by 1.15%, that is, to the level of 46.85 thousand UAH the resulting price remains higher than the average market price – 45.5 thousand UAH, but it is reasonable and will help to increase the competitive position of this technology in the market.

6. Conclusion
As a result of the work carried out, a pricing model for eco-innovative products was developed based on its technological readiness for commercialization. The model was developed using fuzzy set theory algorithms, which made it possible to aggregate various factors influencing the readiness of eco-innovative products, in particular, from the point of view of its developer (manufacturer, seller) and from the point of view of its perception by the market (buyer, consumer, etc.). The model is based on an integral price indicator, which allows you to specify the price of eco-innovative products and determine their place in the market environment within specific time limits.

Hypothesis 1 is true because the pricing model for innovative products, developed on the basis of algorithms of fuzzy set theory, allows to formalize and integrate a set of heterogeneous features that determine the technological readiness of this product. In particular, they are taken into account in the stages of signs of readiness of eco-innovative products from the point of view of the developer (manufacturer, seller) and readiness of eco-innovative products from the point of view of market perception (buyer, consumer, etc.).
Hypothesis 2 is not true, as the developed model is effective for short- and medium-term forecasting periods. If it is used for long-term (strategic) pricing purposes, errors may occur as there will be market factors that are not always predictable. The obtained integral indicators characterize the situation for eco-innovative products in a specific analyzed period (which, in fact, is laid down at the stages of technological readiness of products).

Hypothesis 3 is true – this model can be used for pricing of eco-innovative products of any economic activity, it is universal. Based on the peculiarities of the market situation, the signs of technological readiness of eco-innovative products for commercialization can be supplemented or modified.

References
[1] Afshari H, Searcy C and Jaber M Y 2020 The role of eco-innovation drivers in promoting additive manufacturing in supply chains *International Journal of Production Economics* **223** 107538.
[2] Ma L, Wang L, Skibniewski M J and Gajda W 2019 An eco-innovative framework development for sustainable consumption and production in the construction industry *Technological and Economic Development of Economy* **25(5)** pp 774-801.
[3] Barbieri R and Lopes Santos D F 2020 Sustainable business models and eco-innovation: A life cycle assessment *Journal of Cleaner Production* **266** 121954.
[4] Motta W H, Issberner L-R and Prado P 2018 Life cycle assessment and eco-innovations: What kind of convergence is possible? *Journal of Cleaner Production* **187** pp 1103-1114.
[5] Tamayo-Orbegozo U, Vicente-Molina M-A and Villarreal-Larrinaga O 2017 Eco-innovation strategic model. A multiple-case study from a highly eco-innovative European region *Journal of Cleaner Production* **142** pp 1347-1367.
[6] Bocken N M P, de Pauw I, Bakker C and van der Grinten B 2016 Product design and business model strategies for a circular economy *Journal of Industrial and Production Engineering* **33:5** pp 308-320.
[7] Prendeville S, O'Connor F and Palmer L 2014 Material selection for eco-innovation: SPICE model *Journal of Cleaner Production* **85** pp 31-40.
[8] Myrkhina O, Lisovska L, Novakivskyj I, Terebukh A and Zhukovska V 2020 Method of Modelling Prices for R&D Products in the Case of their Transfer from Engineering Universities to the Business *Advances in Science, Technology and Engineering Systems* **5(5)** pp 80-93.
[9] Golińska P and Kawa A 2015 *Technology Management for Sustainable Production and Logistics* (Berlin: Springer-Verlag Berlin Heidelberg).
[10] Zadeh L 1976 A fuzzy-algorithmic approach to the definition of complex or imprecise concepts *International Journal of Man-Machine Studies* **8(3)** pp 249–291.