# Modeling the selection of innovative strategy for development of industrial enterprises

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*Abstract:* - The assessment of the state of the innovation sphere of Poland in relation to the world level shows that Poland has educational and scientific potential allowing to produce scientific ideas and developments but the level of their commercialization remains low. As a result, Poland lags in terms of such criteria for the development of innovation sphere as labor productivity and financial support for innovation activities. The methodological basis of the study is the theory of fuzzy sets and the matrix approach — in modeling the selection of strategies to stimulate innovative development of industrial enterprises. The construction of a matrix of strategies is based on the diagnosis of the selection of innovation development strategy for industrial entities based on the use of fuzzy set theory in assessing the level of investment attractiveness and innovation potential of enterprises is carried out. Based on the proposed methodological approach, the strategic directions of innovative development of three Polish industrial enterprises are substantiated.

Keywords: - Innovative Strategy; Industrial Enterprise; Management; Development; Potential; Matrix.

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# **1** Introduction

The current period of economic development is characterized by active interaction and rapid changes in production and digital technologies, processes of intellectualization of labor, which are defined by the concepts of the fourth industrial revolution [1]. Economic growth and rating of the country in the world economy are determined by its intellectual capital, ability to generate new ideas and implement them through innovation and investment model of development [2, 3, 4]. The high level of global competition in the market of industrial products, the accelerated dynamics of its technological renewal and digitalization determine the urgency of the problems of effective stimulation of innovation, the main subject of which is traditionally industrial enterprises [5, 6, 7].

The global pandemic of 2020 exacerbated the problems of access to financial resources and capital markets but at the same time identified strategic importance for each country of state support for high-tech industries, including pharmaceuticals, electronics and telecommunications equipment. medical, high-precision and optical technology. The development of such activities is based on increasing the intellectualization of labor and additional requires investment in the commercialization of knowledge and therefore in the innovation [8, 9, 10].

Stimulation of innovative activity in modern economies is carried out by means of a complex of economic tools and levers both in the system of state regulation and market relations [5]. Of particular importance are the issues of streamlining economic instruments and levers to intensify innovation. The solution of the outlined problems requires the implementation of a systematic and balanced state policy in order to increase the efficiency of economic regulation of the innovation sphere [11, 12, 13].

The mechanism for stimulating the innovative activity of industrial enterprises is a component of the model of innovative development of industry, the economy as a whole and its regions, which should ensure sustainable development [14, 15]. Sustainability (equilibrium, balance) is a state of system development in which the actions of various economic and other factors do not cause significant deviations, i.e., development parameters remain within acceptable limits or do not exceed the allowable limits of the system according to its development strategy [16].

On the other hand, the mechanism of stimulating innovation should provide such development that would be most effective for the current generation, while not harming any future generation, therefore, the innovation mechanism should be aimed at saving resources, both natural and material, and increasing the welfare of the population at the present stage [17, 18, 19].

The mechanism of stimulation of innovative activity is a set of actions of administrative character which interconnect and direct development of innovative activity of economic entities in accordance with mission and hierarchy of the longterm purposes of development of entities [20].

Analysis of the organization of the functioning of bodies for regulation of innovation activities gives grounds to assert the lack of systemacity both at the level of formation of the regulatory framework and the activities of regulatory institutions, in particular in the use of appropriate tools [21, 22, 23]. Therefore, methodological approaches to the formation of a system of economic regulation of innovation processes in Poland need improvement. Given the existing approaches to understanding the essence of tools to support innovation in industry, the following definitions of the economic mechanism for stimulating innovation in industrial enterprises are proposed.

From the point of view of the system-structural approach, the economic mechanism of stimulation of innovative activity is a set of economic methods, approaches, tools and levers of influence on innovative activity at all stages of industrial activity for the purpose of ensuring its competitiveness and increasing its contribution to sustainable economic development [24].

From the point of view of understanding the economy and its mechanisms as a system of relations, the economic mechanism of stimulation of innovative activity is a set of procedures and rules of economic relations of economic entities, government institutions and other stakeholders regarding increase in innovation activity at all stages of industrial activity for the purpose of ensuring its competitiveness and increasing its contribution to sustainable economic development [26, 26].

The complexity of the processes of innovation of industrial enterprises necessitates the use of a set of criteria and indicators in the management of these processes [27]. Another requirement, in addition to systemacity, the availability of quality and regular information for decision-making at various levels of management and support for innovation. One of the tools that is actively used in modern management systems, taking into account the above requirements, is the introduction of a monitoring system [28]. In a general sense, monitoring is a set of program-methodological, organizational, technological and other tools that provide regular monitoring of the state of a particular object according to a pre-developed methodology and system of indicators [29].

Thus, as of today the theoretical and methodological basis for the study of the innovation sphere and its state regulation has been formed. However, modern trends in the development of the institutional structure of the innovation sphere, new forms of stimulating the innovative activity of industrial enterprises, taking into account their specifics and the potential for development of strategic industries, require a further study. The importance of the studied issues for the domestic economy is increased by the threatening trend of declining industrial production, low share of innovative products, the need to modernize industry and find new models of its development. The relevance, theoretical and practical significance of these problems led to the selection of the topic of the paper, its purpose, subject, object, and logic of scientific study.

The purpose of the paper is to deepen the theoretical and methodological principles and develop scientific and practical recommendations for modeling the selection of strategies for innovative development of industrial entities in order to justify the directions of their economic stimulation and taking into account investment attractiveness and innovation potential.

# 2 Methodology

of Effective implementation strategies for innovative development of industries requires the presence of internal economic incentives, primarily at the enterprise level. Appropriate management decisions on the selection of strategies for innovative development at the micro level should be based on factors related to the internal and external environment of the enterprise, indicators of its investment attractiveness. Such decisions require the use of a broader information and analytical framework, which is based on financial and other types of reporting of the economic entity. In this regard, it is proposed to carry out modeling of the selection of innovation development strategy and stimulation of its implementation at the micro level taking into account two criteria: investment attractiveness (X); innovation potential (V).

Given the complex nature of these criteria and the level of testing of existing scientific and methodological approaches to their evaluation, it is proposed to measure the level of investment attractiveness and innovation potential of the enterprise using fuzzy set theory and to classify the obtained integrated assessments as follows:

1) for the criterion of "investment attractiveness of the enterprise", to use three levels of values of integrated assessment: "very good", "good", "bad";

2) for the criterion of "innovation potential of the enterprise", to use four levels of values of integrated assessment: "very good", "good", "satisfactory", "bad".

Determining the level of investment attractiveness of the enterprise involves assessing a set of indicators of its financial and economic condition. А well-constructed model of comprehensive analysis of investment attractiveness should contain the optimal number of indicators that reflect only those data that are of interest to the manager or potential investor. In addition, the list of indicators of the model should not include those indicators that duplicate information. In opinion of the authors, the balanced list of investment attractiveness indicators is as follows [31, 32, 33]:

1. The financial independence/autonomy ratio  $(^{X_1})$  that shows the share of own capital in the total capital. The economically feasible value of this ratio should be more than 0.5, i.e., the share of own capital should be at least half of the total capital. It is believed that the investor will be more willing to invest in the company, the greater the share of own capital in the total capital. As then the company is more likely to be able to pay its obligations on its own.

On the other hand, it should be understood that the company will not be able to develop normally if it does not attract external resources, at least in order to replenish working capital.

2. Investment ratio  $(X_2)$  that characterizes the adequacy of the own capital for covering fixed assets and the participation of own capital in the formation of assets. Economically feasible value is more than 1. The higher the value of the indicator compared to 1, the more stable the financial condition of the enterprise.

3. Maneuverability coefficient  $({}^{X_3})$ . Standard value: 0.40–0.60. The increase in the value of this coefficient characterizes the positive changes in the financial condition of the enterprise, as it means that it increases the ability to maneuver with own funds.

4. Current liquidity ratio  $\binom{X_4}{}$  that determines the ability of the company to meet its obligations at the expense of current assets. It is believed that current assets should be 1.5–2.5 times more than debt obligations, i.e., the standard value of this indicator is 1.5–2.5. In this case, the sale of current assets provides settlement of liabilities. A very low value of the ratio indicates a high probability of loss of solvency, and too high value of the ratio indicates an inefficient use of borrowed capital. The current liquidity ratio shows how short-term liabilities are covered by short-term assets, which will have to be converted into money for a period equal to the maturity of liabilities.

5. Return on assets  $({}^{X_5})$  that shows the amount of revenue from sales of products per 1 euro of fixed assets. The greater the return on assets, the more efficient the use of fixed assets, i.e., the capital invested in them.

6. Along with the return on assets, it is important to estimate the ratio of renewal of fixed

assets  $({}^{X_{6}})$ , which characterizes the level of physical and moral renewal of fixed assets. This figure should be constantly increased but always taking into account inflation.

7. Return on equity  $\binom{X_7}{}$  that characterizes the efficiency of use of equity. It is believed that equity is used effectively when its return exceeds the return on long-term investments in the bank.

8. Return on total capital  $(X_8)$  that assesses the operating efficiency of the enterprise.

9. Payables period  $({}^{X_9})$ . This is the average payment period of short-term debt. An increase in the indicator indicates an increase in debt, but in case of this increase it is necessary to pay attention to the ratios of financial dependence and financial stability.

10. Ratio of short-term receivables and payables

 $(^{X_{10}})$  that shows what part of the accounts payable the company can pay at the expense of its debtors during the year. The standard value of this indicator is equal to 1. The lower its value relative to 1, the greater the likelihood of problems with credit repayment.

11. Production profitability  $(X_{11})$  that shows the efficiency of production costs. This indicator is the most qualitative measure of the economic efficiency of production, because it most accurately compares the amount of profit with the size of the costs at which it is obtained.

12. Net profit ratio  $(X_{12})$  allowing the company to increase its working capital and solvency. To ensure self-sufficiency, the company must provide a level of profitability of more than 5 % of turnover.

Analysis of these indicators does not require too broad an information base and does not require much time, it can be regarded as a rapid analysis. Certainly, to make a final decision on the feasibility of investing in the company, the investor may need more information. But in order to take in the situation and draw a minimum of conclusions, this set of indicators is enough.

To assess the innovative potential of the enterprise there is a need to take into account many factors that are the basis for further calculation of the integrated indicator of its level. As indicators of resource provision of the enterprise for the purposes of realization of its innovative potential it is proposed to use a number of such indicators [34]:

1. Intellectual property ratio  $(y_1)$ , which is calculated as the ratio of the value of rights to commercial designations, industrial property, copyright and related rights to the value of intangible assets of the enterprise.

2. Proficiency ratio of personnel  $(y_2)$  involved in the innovation activities of the enterprise, which is the ratio of the number of employees with higher education to the total number of employees involved in the innovation activities.

3. Ratio of enterprise provision with equipment necessary for the innovation activities

 $(y_3)$ , which is calculated as the ratio of the cost of production equipment related to technological innovations to the cost of all production equipment.

4. New technology insertion ratio  $({}^{y_4})$ , which is the ratio of the value of the introduced fixed assets to the average annual value of fixed assets of the machine-building enterprise.

5. Ratio of mastering of new products  $(y_5)$ , which is the volume of sales of new products in value terms divided by the total sales of the enterprise for a certain period of time.

6. Innovation growth ratio  $(y_6)$ , which is calculated as the ratio of enterprise costs for innovation for a certain period of time to the total costs of the enterprise for the same period.

Given the complex nature of the criteria of investment attractiveness and innovation potential, it

is proposed to quantify them using fuzzy set theory and methods of integrated assessment, in particular, double convolution formulas:

$$x_{m} = \sum_{i=1}^{m} A_{i} \sum_{j=1}^{3} B_{j} \times R_{ij}(x_{i}),$$
(1)

$$\mathbf{y}_{n} = \sum_{k=1}^{n} \mathbf{A}_{k} \sum_{j=1}^{n} \mathbf{B}_{j} \times \mathbf{R}_{kj}(\mathbf{y}_{k}),$$
(2)

where  $A_i$  and  $A_k$  – weights of *i*-th and *k*-th basic indicators in the convolution;  $R_{ij}(x_i)$  and  $R_{kj}(x_k)$  – values of membership functions of *j*-th quality level relative to the current value of *i*-th and *k*-th basic indicators;  $B_j$  – nodal points of the standard five-level fuzzy 01-classifier, which value for indicators for which the increase in the value of the indicator corresponds to the improvement of the characteristic is calculated by the formula:  $B^+ = 0.1 + 0.2 \times (i-1)$ ,

$$\mathbf{B}_{j}^{+} = 0.1 + 0.2 \times (j-1), \tag{3}$$

and for indicators for which the increase in the value of the indicator corresponds to the deterioration of the characteristic — by the formula:  $B_{j}^{-} = 0.9 + 0.2 \times (j-1).$  (4)

The standard five-level fuzzy 01-classifier is based on 01-support and allows to describe the five values of the linguistic variable "indicator level": "very low", "low", "medium", "high" and "very high".

A system of five trapezoidal membership functions is used to describe subsets of the values of the linguistic variable "indicator level":

$$R_{i1}(x_{i}) = \begin{cases} 1, \text{if } 0 \le x_{i} < 0.15\\ 10 \times (0.25 - x_{i}), \text{if } 0.15 \le x_{i} < 0.25\\ 0, \text{if } 0.25 \le x_{i} \le 1 \end{cases}$$
(5)

"very low"

w": 
$$\begin{bmatrix} 0, \text{if } 0.25 \le x_i \le 1 \\ 1, \text{if } 0 \le x_i < 0.15 \\ 10 \times (0.25 - x_i), \text{if } 0.15 \le x_i < 0.25 \\ 1, \text{if } 0.25 \le x_i < 0.35 \\ 10 \times (0.45 - x_i), \text{if } 0.35 \le x_i < 0.45 \\ 0, \text{if } 0.45 \le x_i \le 1 \\ \end{bmatrix}$$
(6)

"low":

$$R_{i3}(x_i) = \begin{cases} 0, \text{if } 0 \le x_i < 0.35\\ 10 \times (x_i - 0.35), \text{if } 0.35 \le x_i < 0.45\\ 1, \text{if } 0.45 \le x_i < 0.55\\ 10 \times (0.65 - x_i), \text{if } 0.55 \le x_i < 0.65\\ 0, \text{if } 0.46 \le x_i \le 1 \end{cases}$$
(6)

"medium":

$$R_{i4}(x_{i}) = \begin{cases} 0, \text{if } 0 \le x_{i} < 0.55 \\ 10 \times (x_{i} - 0.55), \text{if } 0.55 \le x_{i} < 0.65 \\ 1, \text{if } 0.65 \le x_{i} < 0.75 \\ 10 \times (0.85 - x_{i}), \text{if } 0.75 \le x_{i} < 0.85 \\ 0, \text{if } 0.85 \le x_{i} \le 1 \end{cases}$$

$$R_{i5}(x_{i}) = \begin{cases} 0, \text{if } 0 \le x_{i} < 0.75 \\ 10 \times (x_{i} - 0.75), \text{if } 0.75 \le x_{i} < 0.85 \\ 1, \text{if } 0.85 \le x_{i} < 1 \end{cases}$$

$$(8)$$

"very high":

"high":

(9)

(7)

In formula (1)  $X_i(y_k)$  is 01-support, and membership functions built on the basis of this system are given in Figure 1.



Figure 1. Standard five-level fuzzy 01-classifier built on the basis of trapezoidal membership functions

The nodal points of the standard five-level fuzzy 01-classifier  $R_{ij}(x_i)$  are, on the one hand, the abscissas of the maxima of the corresponding membership functions on 01-support, and, on the other hand, evenly spaced on 01-support and symmetric with respect to the nodal point 0.5,

namely these are points 0.1; 0.3; 0.5; 0.7; 0.9. These points act as weights when aggregating the system of indicators at the level of their qualitative states. Thus, the nodal points reduce the set of nonstandard classifiers (with their asymmetrically located nodal points) to a single classifier of standard form, with the simultaneous transition from a set of non-standard supports of individual factors to the standard 01-support.

The essence of the five-level fuzzy 01-classifier is that if nothing is known about the indicator, except that it can take any value within the 01support, and it is necessary to make an association between qualitative and quantitative estimates of the indicator, the proposed classifier does so with maximum reliability. With that the sum of all membership functions for any  $A_i$  or  $A_k$  is equal to one, which indicates the consistency of the classifier.

As for the weights of the basic indicators in the convolution a, and "a", in this case it is advisable to determine them by expertise using the Fishburne scale [35].

Each basic indicator of the enterprise  $\mathbf{x}_{i}(i=\overline{\mathbf{1},\mathbf{m}})_{and} \mathbf{y}_{k}(i=\overline{\mathbf{1},\mathbf{n}})_{is matched with the estimate of weight, that is the following system of weights is constructed:$ 

$$\begin{cases} \sum A_{i} = 1, \\ A_{i} \ge 0, \\ i = \overline{1, m} \end{cases} \text{ and } \begin{cases} \sum A_{k} = 1, \\ A_{k} \ge 0, \\ k = \overline{1, n}. \end{cases}$$
(10)

where  $A_i$  and  $A_k$  – *i*-th and *k*-th basic indicators; *i* and *k* – ordinal numbers of the indicators; *n* and *m* – number of the basic indicators on the basis of which integrated indicators *X* and *Y* are determined.

According to the Fishburne principle, the basic indicators are ranked in descending order of weight of  $x_1 > x_2 \sim x_3 > ... > x_i > ... > x_{mand}$   $y_1 > y_2 \sim y_3 > ... > y_k > ... > y_n$  (the sign "~" means that the expert considers a certain pair of indicators to be equivalent), and after ranking their weights are calculated by formulas:

$$A_{i} = \frac{2 \times (m - i + 1)}{m \times (m + 1)} \text{ and } A_{k} = \frac{2 \times (n - k + 1)}{n \times (n + 1)}$$
(11)

The Fishburne rule reflects the fact that nothing is known about the level of weight of indicators except their hierarchy. Then the estimate (11) corresponds to the maximum entropy of the available information uncertainty about the object of study. The resulting weighting factor is calculated as the arithmetic mean of the weights determined by each of the experts.

## **3 Results and Discussion**

The selection of innovation development strategy taking into account the levels of investment attractiveness and innovation potential of an industrial enterprise is proposed to be carried out using the matrix given in Table 1.

Enterprise innovation potential level (V)	Very good	Market niche strategy	Active innovator strategy	Active generator strategy			
	Good	Strategy for targeting knowledge- intensive firms	"Preemptive strike" strategy	Challenge strategy			
	Satisfactory	Opportunistic strategy	Differentiation strategy	Price leadership strategy			
	Bad	Innovative change strategy	Expectation strategy	Simulation strategy			
		Bad	Good	Very good			
		Enterprise investment attractiveness level in the market $(X)$					

Table 1. Matrix for selection of the strategy of innovative development of an industrial enterprise taking into
account its investment attractiveness and innovation potential

Enterprises with a high level of investment attractiveness and innovation potential are proposed to select the generator active strategy (leadership strategy) for innovative development. This strategy is applied to a limited range of products for which release favorable conditions (scientific and technical potential, resources, environment) are created. Scientific studies conducted by economic entities innovation generators - are aimed at production of innovative products in order to displace competitors and enter new markets. Technological and market leadership is based on the development of basic, radical innovations. The implementation of the leadership strategy requires thorough research: a wide front of research work; constant review of the most important results of research in order to implement them in production; operational changes in funding priorities depending on the expected marketing results [12]. Patent licensing measures require special attention.

The active innovator strategy (follow the leader) focuses attention on expanding market positions [16]. An enterprise concentrates on innovations (products) that have recently appeared in the market. An economic entity needs to keep in the second position in the group of applicants for the first position, to implement an effective innovation policy, constantly monitor the research and development of the technological leader and focus on creating scientific achievements in these activities to reduce time and effort of scientific and technical preparation of innovative products before entering the market. Economic entities that adhere to this strategy patent their own innovations, which are based on the innovations of the technological leader [14]. The active innovator strategy is proposed for industrial entities with a satisfactory level of investment attractiveness and high innovation potential.

A differentiation strategy implies the company's desire for uniqueness in any aspect important to customers [24]. Differentiation strategies become relevant when consumer demands become diverse and cannot be met by standard products. A successful differentiation strategy can only be based on a study of consumer demand. A competitive advantage can be expected in the case when a large number of buyers will be interested in purchasing products with differentiated (i.e., different from those produced by competitors) characteristics. Differentiation can be based on differences in the taste properties of the product, its design, service, completeness of the range, reliability, safety.

An innovative change strategy is characteristic of enterprises with low innovation potential and investment attractiveness. The main reason for this situation is outdated uncompetitive products on the market. For innovative development of such enterprise it is important to carry out economic stimulation of professional development of the personnel of an enterprises in a part of its innovative culture, generation of new ideas and developments for updating of products. Table 2 presents the resulting weighting coefficients of the basic/partial indicators of investment attractiveness of an enterprise calculated by formula (11) according to their ranking by experts.

Table 2. Calculation of the weighting coefficients of the basic indicators that characterize the investment attractiveness of an enterprise, according to their ranking by experts

Expert	Weighting coefficients of the basic indicators that characterize the investment attractiveness of an											
1	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>	X <sub>9</sub>	<b>X</b> <sub>10</sub>	<b>X</b> <sub>11</sub>	X <sub>12</sub>
1	0.122	0.122	0.013	0.077	0.064	0.026	0.154	0.141	0.044	0.044	0.103	0.090
2	0.154	0.045	0.045	0.141	0.103	0.090	0.121	0.121	0.064	0.077	0.026	0.013
3	0.096	0.019	0.019	0.090	0.077	0.064	0.154	0.121	0.045	0.045	0.121	0.142
4	0.103	0.051	0.038	0.090	0.071	0.071	0.141	0.154	0.019	0.019	0.122	0.122
5	0.141	0.122	0.013	0.154	0.096	0.096	0.077	0.122	0.045	0.025	0.045	0.064
6	0.141	0.090	0.019	0.019	0.154	0.051	0.122	0.122	0.103	0.038	0.077	0.064
7	0.122	0.051	0.019	0.122	0.071	0.071	0.096	0.154	0.038	0.019	0.096	0.141
Resulting weighting coefficient	0.126	0.071	0.024	0.100	0.091	0.067	0.124	0.134	0.051	0.038	0.084	0.090

Table 3 presents the resulting weighting coefficients of the basic/partial indicators of the level of innovation potential of an enterprise calculated by Formula (11), according to the data on their ranking by experts. Table 3. Calculation of weighting coefficients of the basic indicators that characterize the level of innovation

potential of an enterprise, according to their ranking by experts						
	Weighting coefficients of the basic indicators					
Expert that characterize the level of innovation potential of an enterpris					ise	
	<b>y</b> <sub>1</sub>	<b>y</b> <sub>2</sub>	<b>y</b> <sub>3</sub>	У <sub>4</sub>	<b>y</b> <sub>5</sub>	У <sub>6</sub>
1	0.048	0.262	0.262	0.167	0.167	0.094
2	0.071	0.071	0.262	0.262	0.191	0.143
3	0.049	0.095	0.190	0.190	0.190	0.286
4	0.095	0.286	0.238	0.166	0.049	0.166
5	0.048	0.238	0.286	0.190	0.145	0.095
6	0.167	0.071	0.071	0.262	0.167	0.262
7	0.190	0.143	0.238	0.095	0.048	0.286
Resulting weighting coefficient	0.095	0.167	0.221	0.190	0.137	0.190

The method of modeling the selection of the strategy of innovative development of three machine-building enterprises of Poland is tested in the paper: 'Electron' LLC, LEONI LLC and 'Atom' PJSC. The calculation of the integrated indicators for the positioning of the enterprises in the matrix for the selection of a strategy to stimulate innovation activity was carried out in the application software package Math CAD. To illustrate the sequence of their calculation, an example of calculating the integrated indicators of the matrix for the selection of an innovation development strategy for 'Electron' LLC is given in tabular form (Table 4-5). Table 4. Data for estimating the integrated indicator X m

Tuble 1. Dua for estimating the integrated maleator A_m								
	Weighting	Membership functions for values of basic indicators according to the standard five- level fuzzy 01-classifier						
Normalized values of basic indicators	coefficients of basic indicators	"Very low" $R_{i1}(x_i)$	"Low" $R_{i2}(x_i)$	"Medium" $R_{i3}(x_i)$	"High" $R_{_{i4}}(x_{_i})$	"Very high" R <sub>i5</sub> (x <sub>i</sub> )		

$X_1 = 0.90$	$A_{1} = 0.126$	0	0	0	0	1
$X_2 = 0.90$	$A_{2} = 0.071$	0	0	0	0	1
$x_3 = 0.78$	$A_{3} = 0.024$	0	0	0	0.62	0.38
$X_4 = 0.67$	$A_{4} = 0.100$	0	0	0.14	0.86	0
$X_5 = 0.37$	$A_{5} = 0.091$	0	0.64	0.36	0	0
$X_{6} = 0.27$	$A_{6} = 0.067$	0.18	0.82	0	0	0
$X_{7} = 0.28$	$A_{7} = 0.124$	0.11	0.89	0	0	0
$x_{8} = 0.30$	$A_{8} = 0.134$	+ 0	1	0	0	0
$X_{10} = 0.70$	$A_{10} = 0.038$	0	0	0	1	0
$X_{11} = 0.30$	$A_{11} = 0.084$	0	1	0	0	0
$X_{12} = 0.57$	$A_{12} = 0.090$	0	0	0.66	0.34	0
Nodal poin	$(\mathbf{B}_{j}^{*})$	0.1	0.3	0.5	0.7	0.9
$X_9 = 0.52$	$A_{9} = 0.051$	0	0.1	0.9	0	0
Nodal poin	$(\overline{\mathbf{B}_{j}^{-}})$	0.9	0.7	0.5	0.3	0.1

Table 5. Data for estimating the integrated indicator Y n

Normalized	Weighting coefficients of basic indicators	Membership functions for values of basic indicators according to the standard five- level fuzzy 01-classifier					
values of basic indicators		"Very low" $R_{k1}(x_k)$	"Low" $R_{k2}(x_k)$	"Medium" $R_{k3}(x_k)$	"High" $R_{_{k4}}(x_{_k})$	"Very high" $R_{k5}(x_k)$	
$y_1 = 0.46$	$A_{1} = 0.095$	0	0.21	0.79	0	0	
$y_{2} = 0.50$	$A_{2} = 0.167$	0	0	1	0	0	
$y_{3} = 0.30$	$A_{3} = 0.221$	0	1	0	0	0	
$y_4 = 0.48$	A <sub>4</sub> = 0.190	0	0.1	0.9	0	0	
$y_{5} = 0.25$	$A_{5} = 0.137$	0.27	0.73	0	0	0	
$y_6 = 0.13$	$A_{6} = 0.190$	0.86	0.14	0	0	0	
Nodal poin	$(\mathbf{B}_{j}^{*})$	0.1	0.3	0.5	0.7	0.9	

The calculation based on these tables by formulas (1) and (2) gives the following coordinates for the positioning of "Electron" LLC in the matrix for the selection of the strategy to encourage innovation activity:  $X_m = 0.519$  and  $Y_n = 0.343$ . If the quantitative estimation of the integrated indicators  $X_m$  and  $Y_n$  can be carried out by formulas (1) and (2), to recognize the linguistic levels of these indicators it is necessary to use not the standard five-level 01-classifier, but three- and four-level 01-classifiers, with subsets "Bad", "Good", "Very good" of the linguistic variable "Indicator level", in case of the three-level classifier, and with subsets "Bad", "Satisfactory", "Good", "Very good", in case of the four-level classifier. The transition from five levels to three and four levels is due to the fact that the matrix for the selection of the strategy to encourage innovation activity of enterprises has a dimension of 4x3 (12 positions in total). The rule for recognizing the linguistic values of the integrated indicators  $X_m$  and  $Y_n$  calculated by formulas (1) and (2) are presented in Tables 6-7, respectively.

Table 6. The rule for recognizing the linguistic values of the integrated indicator  $X_m$  – the level of investment attractiveness of an enterprise in the market

Value range X_m	Classification of the levels of investment attractiveness of an enterprise in the market	Level of assessment confidence (membership function)
$0 < X_m < 0.2$	Bad	$R_{1} = 1$
$0.2 \leq V \leq 0.4$	Bad	$R_1 = 5 \times (0.4 - X_m)$
$0.2 \le \Lambda_{\text{III}} \le 0.4$	Good	$R_{2} = 1 - R_{1}$
$0.4 < X_m < 0.6$	Good	$R_{2} = 1$
$0.6 \leq \mathbf{V} \leq 0.9$	Good	$R_2 = 5 \times (0.8 - X_m)$
$0.0 < \Lambda _{III} < 0.8$	Very good	$R_{3} = 1 - R_{2}$
0.8 < X_m < 1.0	Very good	$R_{3} = 1$

Table 7. The rule for recognizing the linguistic values of the integrated indicator  $Y_n$  – the level of innovation potential of an enterprise

Y_n value range	Classification of the levels of innovation potential of an enterprise	Level of assessment confidence (membership function)
$0 \le Y_n < 0.2$	Bad	$R_{1=1}$
$0.2 \le V \le n \le 0.3$	Bad	$R_1 = 10 \times (0.3 - Y_n)$
0.2 = 1 _1 < 0.5	Satisfactory	$R_{2} = 1 - R_{1}$
$0.3 \le Y_n < 0.45$	Satisfactory	$R_{2} = 1$
$0.45 \le Y_n < 0.55$	Satisfactory	$R_2 = 10 \times (0.55 - Y_n)$
	Good	$R_{3} = 1 - R_{2}$
$0.55 \le Y_n < 0.7$	Good	$R_{3} = 1$
$0.7 \le V$ n < 0.8	Good	$R_3 = 10 \times (0.8 - Y_n)$
0.7 \le 1 _ II < 0.0	Very good	$R_4 = 1 - R_3$
$0.8 \le Y_n \le 1$	Very good	$R_4 = 1$

When recognizing according to these rules the linguistic values of the integrated indicators  $X_m$  and  $Y_n$  calculated for "Electron" LLC, one can position the level of the indicator  $X_m$  of the enterprise as "Good", and the level of the indicator Y n as "Satisfactory".

Similarly, the assessment of integrated indicators and positioning in the matrix for the selection of the strategy to encourage innovation activity for other enterprises was carried out. In particular, for LEONI  $X_m = 0.392$ , and  $Y_n = 0.364$ . Recognition of these values using the rules given in Table 6-7 indicates that the level of investment attractiveness of the enterprise in the market is 96% "Good" and 4% "Bad", and the level of innovation potential is 100% "Satisfactory". As for "Atom" PJSC,  $X_m = 0.221$ , and  $Y_n = 0.167$ . When recognizing the linguistic values of these integrated indicators, one can position the level of the indicator  $X_m$  as 90% "Bad" and 10% "Good", and the level of the indicator  $Y_n$  as 100% "Bad".

Based on the carried out calculations one can position the machine-building enterprises under study in the matrix for the selection of the strategy to encourage innovative activity (Figure 2).



Figure 2. Positioning of industrial enterprises in the matrix for the selection of the strategy for innovation development

As a result of positioning of three machinebuilding enterprises the following results were obtained.

- "Atom" PJSC fell into the area of application of the strategy of innovative changes, as it is characterized by a low level of investment attractiveness and innovation potential.

- "Electron" LLC and LEONI LLC fell into the area of application of the differentiation strategy, as they are characterized by a medium level of investment attractiveness and a satisfactory level of innovation potential. However, by the first parameter, i.e., the level of investment attractiveness of the enterprise in the market, LEONI LLC is still quite close to the area of application of opportunistic strategy.

Thus, based on the carried out studies and calculations, the following strategies to stimulate innovation activity can be proposed for each of the machine-building enterprises considered in the paper:

- For "Atom" PJSC, it is advisable to apply the strategy of innovative changes, the essence of which is to upgrade production.

- For "Electron" LLC and LEONI LLC, it is advisable to implement a differentiation strategy,

which is more competitive than innovative. Its essence for these machine-building enterprises consists in the introduction of innovations that improve the existing product range in accordance with consumer needs.

Under conditions of limited access to financial resources, global competition in the market of industrial technologies, such tax incentives can become perspective directions of the state support for innovative activity of the above and other industrial entities:

1) establishment of the annual rate of accelerated depreciation of the third and fourth groups of fixed assets for enterprises implementing innovative projects;

2) for innovative enterprises, payment of land tax in the amount of 50% of the current tax rate, reduction by 50% of value added tax and tax for income received from the implementation of innovative projects (funds are credited to a special account of the taxpayer and used exclusively to finance innovation activity);

3) introduction of a research tax credit for enterprises that do not have the innovative status. Their stimulation consists in reduction of the accrued income tax by an amount equal to the share of costs for innovation activity in the current year, but not more than 50%. Additional support is also required by national enterprises that use the sixth technological mode (biotechnology, nanotechnology, photonics, artificial intelligence) in the production process, in particular, in terms of exemption from customs duties and value added tax on raw materials, equipment, components and other products, which are not produced in Poland.

## **5** Conclusion

In the paper, selection modeling of innovation development strategy for industrial entities (micro level) on the basis of indicators of their investment attractiveness and innovation potential was carried out. Such approach allows to adapt as much as possible the process of making decisions in uncertain market conditions, taking into account the financial and economic condition of each enterprise, regional and sectoral conditions of their development and competitiveness, strengths and weaknesses in innovation activities.

The matrix approach in selection modeling of innovation development strategy of an economic entity was tested for three enterprises of the machine-building industry of Poland. It is emphasized that to implement the proposed innovation strategies at the enterprise level with maximum support from the state and private investors, it is important, firstly, to place information on indicators of innovation activity and investment potential on the company website, secondly, to develop an innovative project that implements the selected strategy, including in cooperation with participants of an industrial or regional cluster or innovation park, and thirdly, to register the project with the Ministry of Science and Higher Education of Poland, which maintains an electronic database of such initiatives.

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Conceptualization, N.M. and H.K.; methodology, N.M.; software, I.L.; validation, A.S.; formal analysis, D.C.; investigation, H.K.; resources, I.L.; data curation, A.S.; writing—original draft preparation, D.C.; writing—review and editing, N.M.; visualization, H.K.; supervision, I.L.; project administration, A.S.; funding acquisition, D.C. All authors have read and agreed to the published version of the manuscript.

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