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EFFICIENCY OF TECHNOLOGICAL MANAGEMENT IN INNOVATION CLUSTERS BY COMPONENTS: EDUCATION, PERSONNEL DEVELOPMENT AND LOGISTICS

The article is devoted to the method of evaluating the effectiveness of technological management in innovation clusters by components: education, personnel and logistics. Attention is focused on the need to activate cluster development in the context of the post-war reconstruction of Ukraine, because it is innovative clusters that have the ability to accumulate the necessary amount of financial resources, as well as to form the necessary labor potential, which significantly increases the effectiveness of innovative activities. It was determined that in order to increase the effectiveness of the implementation of the technological potential, it is appropriate to monitor the integral coefficient and partial coefficients that characterize the implementation of the technological potential within the innovation cluster and its individual components. The methodology for calculating such a coefficient is proposed and tested within the innovation cluster.

Keywords: *education, innovation, logistics, personnel, clusters, post-war reconstruction, management, technologies.*

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ЕФЕКТИВНІСТЬ ТЕХНОЛОГІЧНОГО МЕНЕДЖМЕНТУ В ІННОВАЦІЙНИХ КЛАСТЕРАХ ЗА КОМПОНЕНТАМИ: ОСВІТА, РОЗВИТОК ПЕРСОНАЛУ ТА ЛОГІСТИКА

Стаття присвячена методиці оцінювання ефективності технологічного менеджменту в інноваційних кластерах за компонентами: освіта, персонал та логістика. Акцентовано увагу на необхідності активізації кластерного розвитку в контексті післявоєнного відновлення України, адже саме інноваційні кластери мають здатність акумулювати потрібний обсяг фінансових ресурсів, а також сформувати необхідний трудовий потенціал, що значно підвищує результативність інноваційної діяльності. Визначено, що задля підвищення ефективності реалізації технологічного потенціалу доречно здійснювати моніторинг інтегрального коефіцієнту та часткових коефіцієнтів, які характеризують реалізацію технологічного потенціалу в межах інноваційного кластеру та окремих його компонент. Запропоновано методику розрахунку такого коефіцієнту та апробовано її в межах інноваційного кластеру.

Ключові слова: *освіта, інновації, логістика, персонал, кластери, післявоєнне відновлення, менеджмент, технології.*

Табл. 10. Рис. 3. Літ. 15.

Formulation of the problem. The development of innovative entrepreneurship is the key to achieving the strategic goals of the state because it allows to optimal use of the available potential of the country for the growth of social and economic living standards of the population, to ensure sustainable development of the country, to ensure the security of citizens, business and the state. However, the importance of innovative

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entrepreneurship is growing in conditions when Ukraine has experienced significant devastation from military aggression by the Russian Federation. Despite the fact that the war is not yet over, it is necessary to form measures for the reconstruction of Ukraine in the post-war period. The renewal process can be divided into several stages: emergency, critical, tactical and strategic. The emergency stage involves measures implemented immediately or in the first hours after the occurrence of destruction. The critical stage involves measures aimed at the early restoration of critical infrastructure.

The solution to the problems arising in the context of Ukraine's reconstruction in the post-war period cannot be imagined without ensuring the innovative development of the Ukrainian economy, providing for the generation and accumulation of new knowledge and its transformation into innovative goods and services. For Ukrainian entities, the development, acquisition and implementation of innovative technologies is relevant not only because of the possibility to offer markets a new product or service. The importance of innovation implementation is conditioned by the possibility to reduce the energy intensity of production and energy dependence on imported energy resources, to increase labour productivity, i.e. to reduce the cost of production.

In the context of Ukraine's post-war reconstruction, cluster innovations attract particular attention, because it is innovation clusters that have the ability to accumulate the necessary amount of financial resources, as well as to form the necessary labour potential, which significantly increases the effectiveness of innovation activity.

This requires from the managerial staff of economic entities to attract the tools of technological management, in particular, through the complex nature of the process of innovation activity.

Analysis of recent research and publications. The term technological management began to be used since the mid-60s. There are many approaches to revealing the essence of this term. Using VOSviewer, a terminology map was constructed to reflect the shared use of terms. The resulting term-sharing map is shown in Figure 1.

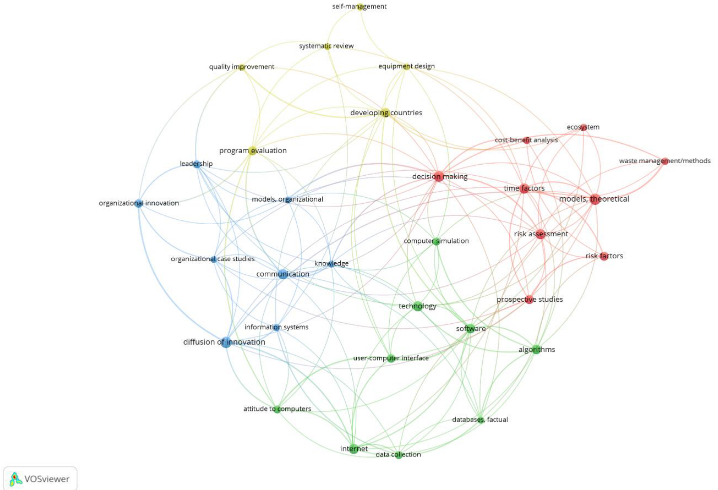

Figure 1. **Terminological map of interrelated terms in scientific papers,** *developed by the author based on information obtained from the Lens database (https://www.lens.org/)*

The visualisation suggests that the size of the nodes depends on the weight of the terms, the length and thickness of the lines reflect the strength of the connection between terms. Terms decorated with the same colour belong to the same cluster. The bibliographic database Lens was used for the analysis, which at the time of the query had 25,630,0428 scientific papers. The query, which included the terms “technology management” and “management of technologies”, resulted in the selection of 17311 papers. After setting a threshold of 10 occurrences, 32 terms were identified as those most frequently occurring in technology management publications. The defined terms were divided into four clusters. In the first cluster, marked in red, the following terms have the highest weight values: “theoretical models”, “decision making”, “risk assessment”, “time factors” and “risk factors”. In the second cluster, marked in green, the most used terms are: “technology”, “algorithms”, and “software”. For the third cluster, marked in blue, the most used terms are: “technology diffusion”, “communications”, and “organisational innovation”. The fourth cluster, marked in yellow, includes the following most used terms: “developing countries”, “evaluation of programme”, “self-management” and “quality improvement”. The analysis of the terms indicates that technological management is an organic component of the overall management system, realising its functions in the context of technological development at all levels of management.

Various aspects of technology management are the subject of research by many scholars. Thus, Chanaron and Jolly, [1], in their work investigate the essence and interrelation of the terms R&D management, management of technologies and technology management. The authors emphasise that the peculiarity of technological management is the focus on the management of technological changes that affect business processes and the absence of resource allocation function. Implementation of technology management is reasonable not only at high-tech enterprises because, at enterprises that use outdated technologies in their business processes, the introduction of a technology management system allows them to effectively implement new technologies and achieve the settled goals. Chanaron and Jolly, [1], also point out that technology penetrates beyond technical issues and involves a wide range of enterprise specialists. This leads to an increased role of the human resource management system because of the implementation of the latest technologies in the enterprise of appropriate training, in particular the knowledge and skills required to integrate technological changes into the business processes of the enterprise. Later, Chanaron et al., [2], continue to explore technology as a complex factor in management system. The authors analyse the use of technology as a resource and specific activity in finance, human resource management, organisational behaviour, marketing and operations management.

Huergo, [3], analyses the impact of technological management on innovations in the case of Spanish enterprises and evaluates the incentive effect of the scale of production on technological activity. Based on the results of the analysis, the author draws the following conclusions: firstly, the involvement of a technological management system has a significant impact on innovation activity, but the level of influence depends on the industry and the nature of innovation. Second, the efficiency of innovation activity is affected by the size of the economic entity, but the impact is not so much due to economies of scale, but due to a more intensive use of technological resources.

The problems of the development of technological management as a source of growth of competitiveness of industrial enterprises are investigated by Vinas et al., [4], on the example of the industrial sector of Cuba.

Scientists emphasise the importance of the implementation of technological management tools for countries with developing economies. After all, due to the increase in the efficiency of technological management, it is possible to solve the problems typical for enterprises functioning in the conditions of a developing economy, namely: low flexibility of organisational structure, low level of awareness, low level of interaction between separate divisions, an underdeveloped motivational component of personnel management.

Brownsword, [5], in his work considers technology management as a regulatory tool. The author proposes an extended concept of "regulatory environment", emphasising the complexity of this environment. The proposed concept unfolds in normative and non-normative dimensions, paying attention to the transition from normative prescriptions to non-normative specifications.

Yi, [6], considers the peculiarities of technological management implementation in the conditions of small and medium-sized enterprises. The scientist notes the importance of technology implementation to ensure the necessary level of competitiveness of enterprises. Analysing the functioning of small and medium-sized enterprises in South Korea, the author draws attention to the need to maintain a balance between the implementation of technology and labour market conditions, in particular, suggests a balanced approach to the implementation of innovations at the microeconomic level and increase the effectiveness of government involvement in ensuring this balance at the macro level.

Ambrosio, [7], in his work explores the problems faced by Spanish industrial enterprises during the recovery period, in particular, he identifies two main problems: the low rate of growth in the number of enterprises in response to increasing demand, and the low level of technological development of enterprises and dependence on external technologies. The scholar stresses that these problems can be solved by linking technology creation centres to consumers and ensuring the effective promotion of technology from inventors to users.

Teran-Bustamante et al., [8], in their work, study the impact of the technological management model on the innovation activity of the enterprise on the example of enterprises in Mexico. The authors note that the developed model of technological management, which involves the influence on the critical factors of innovations and technology management, allows for increasing the level of quality of managerial decisions. Researchers consider the following factors to be the most important for enterprises of a mature low-tech industry: knowledge management, organisational architecture, technological architecture, marketing policy, and waste management.

Tsuji, [9],) explores specific aspects of technological management in the field of telemedicine. He emphasises that in the process of implementing innovative technologies in this area, interaction with government agencies and the implementation of joint projects with local authorities play a significant role.

Enciso et al., [10], also explore the sectoral peculiarities of technology management, analysing the differences between the management of "mature" and innovative technologies in the field of university education. The authors note that the current challenges for the technological management of innovative technologies at the university level are the urgent need to attract investment in research projects and promote innovative technologies from the developer to the consumer. Enciso, Correa & Hernбndez propose to develop a system of effective industrial, social and economic relations between higher education institutions and organisations, which will allow much more effective promotion of innovative technologies on the market.

Liang et al., [11], in their work analyse the specifics of the implementation of technological management functions in the field of oil refining on the example of China National Petroleum Corporation. Researchers emphasise that a significant contribution to improving the efficiency of innovation activities has a two-tier model of innovation projects, a system of control over the use of trust funds, optimisation of the management structure, and integration of the training system.

In the agricultural sector, Burrell et al., [12], analyse the introduction of new technologies to increase productivity and move closer to solving the global food crisis. Burrell et al. draw attention to the need to implement new educational programmes for workers in the agricultural sector.

Specific educational programmes should be implemented at the university and high school level and the aim is to inform about available innovative technologies, information security and cyber security issues.

In a scientific study, Munteanu, [13], analyses the essence of technology management, defining two approaches: technology management characterised as a specific activity and technology management as a specific resource of the enterprise. The author emphasises that technology is a critical factor in the success of an enterprise and, as a result, technology is significantly integrated into the management system. Pomaquero et al., [14], did a meta-analysis of the literature on technology management and innovation in the organisation. Researchers note that companies use innovative and mature technologies on a daily basis to gain competitive advantages, because through the use of technology management tools, the company is able to increase productivity and customer satisfaction and improve safety According to the authors, technology is of strategic importance, and decisions within technology management affect all aspects of enterprise functioning. The result of this is the growing role of awareness of management personnel regarding innovative technologies.

Gomeseria, [15], examines the specifics of the implementation of innovative technologies and technological management in the construction industry, noting the dramatic changes in technology over the previous 6-7 years. The author analyses individual innovative technologies, their implementation and their impact on the functioning of a construction company. Gomeseria emphasises the importance of implementing innovations in the construction industry, as it allows for accelerating the realisation of projects, reducing costs and improving the quality of construction.

Many scientific works analyse various issues related to technology management, but the specifics of technology management within the innovation cluster remain insufficiently covered and require study that is more detailed.

The aim of the article is to investigate the peculiarities of technological management in the context of innovative cluster activities in the education system, personnel development and logistics in the process of post-war reconstruction of Ukraine.

The main results of the study. In the framework of the current study, technological management is considered as a set of principles, approaches and methods of generation and implementation of managerial decisions both at the cluster level and within individual cluster members, aimed at the effective realisation of the available technological potential, as well as the formation and development of the technological potential of the innovation cluster. The functional nature of technological management provides for the permanent technological development of the cluster and its participants, which is now taking place in the conditions of military aggression of the Russian Federation, and in the future – after the post-war reconstruction of Ukraine.

Cluster functioning is characterised by a more complex management structure, more complex relations between cluster members and certain advantages of synergy effect realisation.

The essence of technology management is implemented through functions, in particular, within the cluster at the level of individual participants the following functions can be distinguished: inventory of attracted technologies, structuring of attracted technologies, analysis of technologies available on the market, determination of the level of compliance of attracted technologies at the level of participants and at the level of the cluster, optimisation of attracted technologies, search or development and implementation of new technologies, analysis and adjustment of the introduction of new technologies at the level of participants, analysis and adjustment of the implementation of new technologies at the level of cluster. The functions of technology management are depicted in Fig. 2.

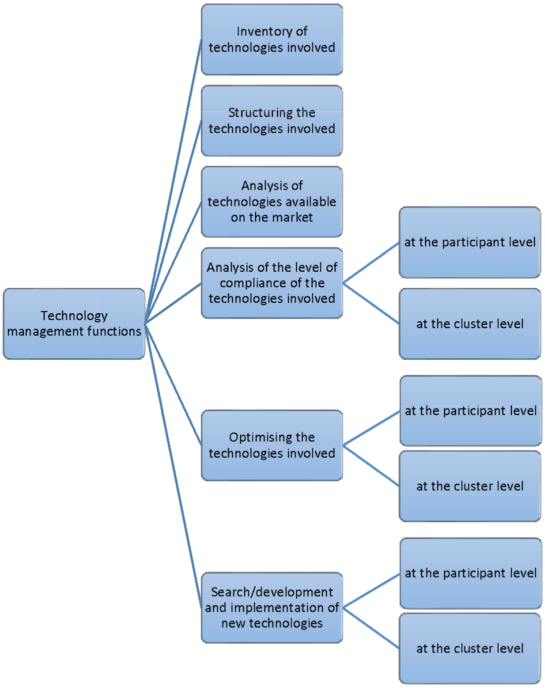

Fig. 2. **Functions of technological management,** *author's development*

The specifics of cluster functioning allow to obtain a synergetic effect in the process of implementation of technological management functions. Implementation of innovative technologies at the level of cluster members is aimed at developing and launching innovative products, improving the quality and expanding the consumer properties of products, covering a larger market share, increasing the competitiveness of products of cluster members, optimising the organisational and management structure, increasing human resources and the efficiency of its implementation, increasing the profitability and investment attractiveness of cluster members.

The process of implementation of technological management both at the cluster level and at its individual participants implies compliance with the principles of systematicity and expediency. The principle of systematicity implies that the implementation of new technologies takes into account the impact on all cluster members and their subsystems. An important aspect of the implementation of this principle is the synchronisation of efforts of individual cluster members in the process of optimising the technologies implemented, as well as in the process of development and implementation of innovative technologies. In turn, the principle of expediency allows ensuring the rational use of involved technologies and available resources. The development of technological potential is closely related to human resources potential because it is the human resources potential that determines the speed and quality of the process of development and implementation of innovative technologies. Therefore, implementing the tools of technological management, it is advisable to allocate the components "Education" and "Personnel Development" in the cluster structure, covering the formation of human resources potential and its development. The "Logistics" component is also important because it significantly affects the promotion of innovative technologies.

In order to improve the efficiency of the innovation activity of the cluster and the competitiveness of its participants, it is advisable to develop the cluster structure in the direction of synchronisation of the components "Education", "Personnel Development", and "Logistics". Thus, the "Education" component may include educational institutions, research institutions, as well as relevant departments of the cluster participants that take part in the formation of the human resources potential of the cluster participants. The "Personnel Development" component may include enterprises and profile subdivisions of the cluster participants engaged in personnel development of the cluster participants. The "Logistics" component may include individual logistics companies and logistics units of cluster participants.

The implementation of technology management within the innovation cluster is associated with certain features due to the specifics of the innovation cluster functioning. In order to ensure effective technology management at the cluster level, it is advisable to monitor the integral indicator of the effectiveness of the implementation of the technological potential of the cluster. For this purpose, it is advisable to calculate the integral indicator according to the formula (1)

$$IIP = \sum_{i=1}^{k} \alpha_i \cdot P_i , \quad (1)$$

where IIP – is an integral indicator characterising the efficiency of implementation of the cluster's technological potential;

P_i – coefficient of realisation of innovation potential;

ith – component of the cluster;

α_i-weighting coefficient of results ith component of the cluster.

Analysis of the dynamics of this coefficient helps to assess changes in the efficiency of technological management of the innovation cluster by determining the efficiency of the realisation of the technological potential of the cluster.

$$IIP = \alpha_e \cdot P_e + \alpha_{hr} \cdot P_{hr} + \alpha_l \cdot P_l \quad (2)$$

P_e – coefficient of realisation of innovative potential of the "Education" component,

P_{hr} – coefficient of realisation of innovative potential of the "Personnel Development" component,

P_l – coefficient of realisation of the innovative potential of the "Logistics" component,

α_{hr} – weight coefficient of the results of the "Education" component,

α_e – weighting coefficient of the results of the "Personnel Development" component,

α_l – weighting coefficient of the results of the "Logistics" component.

The algorithm for determining the integral indicator involves determining the coefficient of realisation of the technological potential of individual cluster members. This indicator reflects the current state of realisation of the available technological potential of an individual cluster member, which makes it possible to assess the effectiveness of technological management

For an individual ith cluster member it is reasonable to calculate this coefficient according to the formula (3):

$$P_i = \sum_{j=1}^{m} \beta_j \cdot X_j \quad (3)$$

where X_j – is the jth indicator characterising the realisation of technological potential;

β_j – weight coefficient of the jth indicator;

m – number of separate indicators used to analyse the implementation of technological potential;

In order to determine the weighting coefficients of indicators that make up the coefficient of technological potential realisation, it is advisable to use formula (4).

$$\beta_j = \gamma_j \cdot \left(\sum_{j=1}^{m} \gamma_j\right)^{-1}, \quad (4)$$

where β_j – weight coefficient of *j*th indicator;

m – number of individual indicators used to analyse the realisation of technological potential;

γ_j – rank of the jth indicator, which is determined based on the priorit, Pr_j – priority of jth indicator of the technological potential of the enterprise.

The formation of the ranking is based on the principle that the higher Pr_j the higher the value γ_j.

Priority Pr_j can be determined by the method of expert evaluations, which allows for obtaining more accurate information necessary for building an integral indicator and making management decisions. On the basis of Pr_j, the rank of the indicator γ_j is determined

Using the method of expert evaluations, it is advisable to check the expert values of ranks for inconsistency. If the value is inconsistent, there is a decrease in the statistical reliability of the obtained information, which negatively affects the effectiveness of technological management. The check can be realised with the help of Kendall's coefficient of concordance, which makes it possible to assess the level of consistency of ranks, based on the fact that the distribution of expert evaluations should follow the normal law. Kendall's coefficient is defined as the ratio of the total variance to the maximum variance. The value of the coefficient falls within the range [0; 1]. If the expert judgements are absolutely consistent, the coefficient will take the value of 1. However, a sufficient level of consistency of the ranks will be the level at which the value of the coefficient of concordance falls within the range of [0,3; 0,7]. The Kendall's coefficient is determined by the formula (5):

$$\omega = 12 \cdot \sum_{i} \left(\sum_{i=1}^{n} \gamma_{ij} - \bar{\gamma} \right)^2 \cdot \left(\delta^2 (n^3 - n) \right)^{-1} \tag{5}$$

$$\bar{\gamma} = \sum_{j} \sum_{i} \gamma_{ij} \cdot n^{-1} \tag{6}$$

where ω – Kendall's coefficient;

γ_{ij} – ranking provided by jth expert to the ith object;

γ – arithmetic mean of the ranks;

$i \in [1, n], j \in (1, \delta)$;

δ – number of experts;

n – sample size.

It is also important to determine the consistency using Pearson's criterion. For this purpose, the number of experts δ is multiplied by the number of degrees of freedom (n-1) and the concordance coefficient ω by the formula (7):

$$Q = \delta \cdot (n - 1) \cdot \omega \tag{7}$$

The obtained value Q is compared with the tabulated value of Pearson's criterion and, if the calculated value exceeds the critical value, it is said that there is

Kendall's coefficient. Exceeds the critical value, it is said about the existence of Kendall's coefficient. The excess of the critical value over the calculated value indicates a low consistency of the concordance coefficient and the need to increase the number of experts.

Thanks to expert analysis, a set of weighting coefficients β is formed which allows calculating the total integral indicator.

The information base of the current study is the data obtained from the innovation cluster participants, which characterise the cluster activities in the context of education, personnel development and logistics. Highly qualified specialists of individual cluster participants were involved as experts. Expert assessments allowed us to determine weighting coefficients for selected indicators.

The following indicators were selected for the "Education" component to characterise the technological potential. The indicators and symbols are given in the table.

Table 1. **Indicators and symbols for the "Education" component,** *author's elaboration*

Indicator	Symbolic designation
Level of realisation of planned training	X_{De1}
Share of training costs in the structure of labour costs	X_{De2}
Share of expenditures on the introduction of innovative technologies in the educational process	X_{De3}
The level of relevance of the curriculum	X_{De4}

The following indicators were selected for the "Personnel Development" component to characterise the technological potential. The indicators and symbols are given in Table 2.

Table 2. **Indicators and symbols for the component "Staff development"?**
author's elaboration

Indicator	Symbolic designation
Level of realisation of the staff development programme	X_{Dh1}
Number of innovative ideas to the number of staff participating in the development programme	X_{Dh2}
Share of expenditures on the implementation of innovative technologies in the personnel development process	X_{Dh3}
Efficiency in the use of the working time fund	X_{Dh4}
Share of technological or other losses due to human error	X_{Dh5}

The following indicators were selected for the "Logistics" component to characterise the technological potential. The indicators and symbols are given in the table.

The level of profitability of activities realised with the use of innovative technologies X_Dl4

Source:

Then the calculation of coefficients of realisation of the technological potential of individual cluster participants will be carried out using formulas adapted to the selected indicators because some of the indicators highlight the negative impact on the efficiency of technological potential realisation.

Table 3. **Indicators and symbols for the Logistics component,** *author's elaboration*

Indicator	Symbolic designation
Share of expenditures on the implementation of innovative technologies	X_{Dl1}
Share of technological losses	X_{Dl2}
Efficiency of digitalisation of logistics processes	X_{Dl3}
The level of profitability of activities realised with the use of innovative technologies	X_{Dl4}

Thus, for the component "Education" this coefficient should be calculated by formula (8):

$$P_e = \beta_{De1} \cdot X_{De1} + \beta_{De2} \cdot X_{De2} + \beta_{De3} \cdot X_{De3} + \beta_{De4} \cdot X_{De4} \quad (8)$$

where β_{Dej} – weight coefficient of jth indicator X_{Dej}. While for the component "Personnel Development" this coefficient will be calculated according to formula (9):

$$P_{hr} = \beta_{Dh1} \cdot X_{Dh1} + \beta_{Dh2} \cdot X_{Dh2} + \beta_{Dh3} \cdot X_{Dh3} + \beta_{Dh4} \cdot X_{Dh4} + \beta_{Dh5} \cdot (1 - X_{Dh5}) \quad (9)$$

where β_{Dhj} – weight coefficient of *j*th indicator X_{Dhj}. In addition, for the "Logistics" component it is reasonable to calculate the coefficient of technological epotential realisation by formula (10):

$$P_l = \beta_{Dl1} \cdot X_{Dl1} + \beta_{Dl2} \cdot (1 - X_{Dl2}) + \beta_{Dl3} \cdot X_{Dl3} + \beta_{Dl4} \cdot X_{Dl4} \quad (10)$$

where β_{Dlj} – weight coefficient of jth indicator $\mathbf{X}_{Dlj}$. Priorities and ranks, as well as weighting coefficients for the selected indicators were determined using the method of expert assessments. The results of the calculations are presented in the tables. For the component "Education", the results of calculations are shown in Table 4.

Table 4. **Priorities, ranks and weighting coefficients for the "Education" component,** *calculated by the author*

Indicators	Priorities				Ranks				Weighting coefficients				
	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4	
X_{De1}	2	1	2	2	3	4	3	3	0,3	0,4	0,3	0,3	0,325
X_{De2}	1	2	1	1	4	3	4	4	0,4	0,3	0,4	0,4	0,375
X_{De3}	3	4	3	3	2	1	2	2	0,2	0,1	0,2	0,2	0,175
X_{De4}	4	3	4	4	1	2	1	1	0,1	0,2	0,1	0,1	0,125

For the "Staff Development" component, the results of the calculations are summarised in Table 5.

Table 5. **Priorities, ranks and weighting coefficients for the "Staff development" component,** *calculated by the author*

Indicators	Priorities				Ranks				Weighting coefficients				
	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4	
X_{Dh1}	3	2	3	3	3	4	3	3	0,20	0,27	0,20	0,20	0,217
X_{Dh2}	2	3	2	2	4	3	4	4	0,27	0,20	0,27	0,27	0,250
X_{Dh3}	4	5	4	4	2	1	2	2	0,13	0,07	0,13	0,13	0,117
X_{Dh4}	5	4	5	5	1	2	1	1	0,07	0,13	0,07	0,07	0,083
X_{Dh5}	1	1	1	1	5	5	5	5	0,33	0,33	0,33	0,33	0,333

For the "Logistics" component, the results of the calculations are shown in Table 6.

Table 6. **Priorities, ranks and weighting coefficients for the "Logistics" component** *calculated by the author*

Indicators	Priorities				Ranks				Weighting coefficients				
	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4	
X_{Dl1}	4	3	4	4	1	2	1	1	0,1	0,2	0,1	0,1	0,125
X_{Dl2}	2	1	2	1	3	4	3	4	0,3	0,4	0,3	0,4	0,350
X_{Dl3}	3	4	3	3	2	1	2	2	0,2	0,1	0,2	0,2	0,175
X_{Dl4}	1	2	1	2	4	3	4	3	0,4	0,3	0,4	0,3	0,350

The consistency of the expert's opinions was checked using the concordance coefficient. Thus, for the component "Education" Kendall's coefficient ϖ was obtained equal to 0.85. This value of the coefficient indicates a high level of consistency of expert's opinions.

It is also important to determine the significance of the concordance coefficient by Pearson's coefficient. The calculated value of Pearson's criterion is Q=4 (4 - 1) 0,85=10,2. A comparison of the obtained value of Pearson's criterion with the critical value equal to 7.815 allows us to conclude that the coefficient of concordance is significant. The calculated value of Pearson's criterion exceeds the critical value, so the obtained results are meaningful and can be used in further researches. For the component "Personnel Development", the coefficient of concordance is 0.92 and reflects a high level of consistency of expert opinions. The Pearson's coefficient is 14.925 and exceeds the critical value. For the "Logistics" component, the concordance coefficient is 0.825 and the Pearson's coefficient value is 9.9, indicating the consistency of the expert's opinions and the statistical significance of the concordance coefficient.

The following data were obtained as a result of the survey of the innovation cluster's activities for the period from 2019 to 2021. For the "Education" component, the X_{Dei} indicators for the period 2019-2021 are shown in Table 7.

Table 7. **"Education" component indicators for the period 2019-2021,** *calculated by the author*

Indicators	Priorities				Ranks				Weighting coefficients				
	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4	
X_{Dl1}	4	3	4	4	1	2	1	1	0,1	0,2	0,1	0,1	0,125
X_{Dl2}	2	1	2	1	3	4	3	4	0,3	0,4	0,3	0,4	0,350
X_{Dl3}	3	4	3	3	2	1	2	2	0,2	0,1	0,2	0,2	0,175
X_{Dl4}	1	2	1	2	4	3	4	3	0,4	0,3	0,4	0,3	0,350

For the "Staff development" component, the indicators X_{Dhi} for the period 2019-2021 are shown in Table 8.

Table 8. **Indicators of the "Staff development" component for the period 2019-2021, calculated by the author**

Indicators	2019	2020	2021
X_{Dh1}	0,98	0,95	0,96
X_{Dh2}	0,07	0,1	0,11
X_{Dh3}	0,18	0,11	0,12
X_{Dh4}	0,94	0,87	0,93
X_{Dh5}	0,027	0,021	0,023

For the "logistics" component, the indicators X_{Dli} for the period from 2019 to 2021 are shown in Table 9.

Table 9. **Logistics component indicators for the period 2019-2021,**calculated by the author

Indicators	2019	2020	2021
X_{Dl1}	0,13	0,21	0,2
X_{Dl2}	0,03	0,0289	0,0278
X_{Dl3}	0,73	0,75	0,76
X_{Dl4}	0,14	0,23	0,24

Based on the obtained indicators X_{Dei}, X_{Dhi} X_{Dli} coefficients were calculated P_e, P_{hr}, P_l and integral indicator – *IIP*.

For example, for 2019, the definition of coefficients is as follows:

$$P_e^{2019} = \beta_{De1} \cdot X_{De1} + \beta_{De2} \cdot X_{De2} + \beta_{De3} \cdot X_{De3} + \beta_{De4} \cdot X_{De4} = 0{,}325 \cdot 0{,}97 + 0{,}375 \cdot 0{,}11 + 0{,}175 \cdot 0{,}17 + 0{,}125 \cdot 0{,}81 = 0{,}488;$$

$$P_{hr}^{2019} = \beta_{Dh1} \cdot X_{Dh1} + \beta_{Dh2} \cdot X_{Dh2} + \beta_{Dh3} \cdot X_{Dh3} + \beta_{Dh4} \cdot X_{Dh4} + \beta_{Dh5} \cdot (1 - X_{Dh5}) = 0{,}217 \cdot 0{,}98 + 0{,}25 \cdot 0{,}07 + 0{,}117 \cdot 0{,}18 + 0{,}083 \cdot 0{,}94 + 0{,}333 \cdot (1 - 0{,}027) = 0{,}654;$$

$$P_l^{2019} = \beta_{Dl1} \cdot X_{Dl1} + \beta_{Dl2} \cdot (1 - X_{Dl2}) + \beta_{Dl3} \cdot X_{Dl3} + \beta_{Dl4} \cdot X_{Dl4} = 0{,}125 \cdot 0{,}13 + 0{,}35 \cdot (1 - 0{,}03) + 0{,}175 \cdot 0{,}73 + 0{,}35 \cdot 0{,}14 = 0{,}533.$$

To calculate IIP within the current study, the weighting coefficients α_e, α_{hr}, α_l have a value of 1. Determination of optimal weighting coefficients for individual components of the innovation cluster can be the subject of further research.

$$IIP^{2019} = 0{,}488 + 0{,}654 + 0{,}533 = 1{,}674.$$

The result of the calculation of integral and share coefficients is shown in Table 10.

Table 10. **Integral and partial coefficients for 2019-2021,** *calculated by the author*

Coefficients	2019	2020	2021
P_e	0,488	0,438	0,460
P_{hr}	0,654	0,643	0,653
P_l	0,533	0,578	0,582
IIP	1,674	1,659	1,695

The dynamics of coefficients calculated based on the results of the innovation cluster activity is reflected in Fig. 2 and Fig. 3.

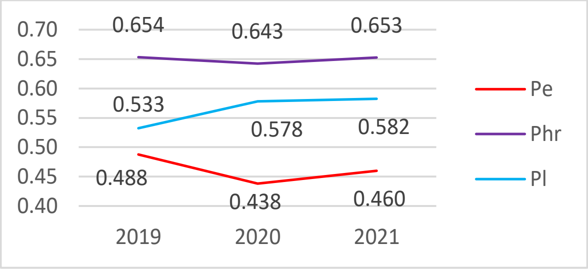

Fig. 2. **Dynamics of partial coefficients in 2019-2021,** *author's development*

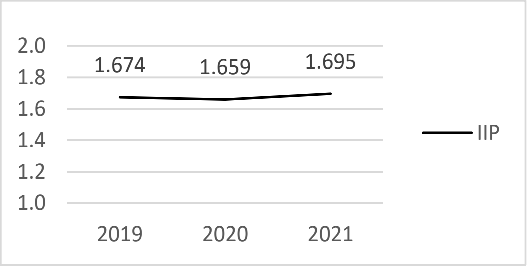

Fig. 3. **Dynamics of the integral coefficient in 2019-2021,** *author's development*

The obtained data indicate that the efficiency of the realisation of the technological potential of the innovation cluster for the period 2019-2021 increased by 1.28%, including a decrease of 0.089% in the period 2019-2020, and in the period 2020-2021 there was an increase of 2.19 %. The growth of the overall integral indicator was due to the growth of the indicator characterising the "Logistics" component.

Largely, this situation is explained by the decrease in business activity due to the restrictive measures related to the COVID-19 pandemic.

In the period 2019-2021 for the component "Education" there was a decrease in the value of the coefficient P_e by 5.6%, in particular, in the period 2019-2020 the efficiency of realisation of technological potential decreased by 10.1%, and in 2020-2021 – increased by 4.96%.

In the period under study, the "Personnel development" component is also characterised by a decrease in the coefficient P_hr by 0.13%. However, the trend is positive, because, in the period 2020-2021, there was an increase in the coefficient by 1.6%, while in 2019-2020 there was a decrease of 1.7%.

Particular attention is drawn to the "Logistics" component, which, unlike other components, is characterised by an increase in the coefficient of *Pl* between 2019 and 2020 by 8.5%, with an increase of 0.76% in 2021. The overall increase in the coefficient *Pl* between 2019 and 2021 is 9.3 %.

The decline in 2020 is largely a result of the COVID-19 pandemic, lower business activity and further government intervention to overcome the pandemic and its consequences. However, the 2021 results show an increase in the partial coefficients characterising the individual components of the innovation cluster and the integral indicator. This indicates that the cluster participants adapted to the new conditions and achieved an increase in technological potential.

Conclusions. The development of technological management system is becoming one of the key management tasks both at the level of an individual enterprise and at the level of innovation-integrated structures. First of all, this is due to the global trend, which implies the formation of economic relations aimed at technological transformation and adaptation of all management subsystems to modern conditions. In the conditions of the post-war reconstruction of Ukraine, it is necessary to pay attention to the introduction of technological management tools, in particular, in the practice of cluster innovation development. Innovation clusters have significant advantages in the conditions of post-war reconstruction of the country, they are able to form the necessary amount of financial resources, develop labour potential and research infrastructure, etc. In the structure of the innovation cluster, it is advisable to identify the components "Education", "Personnel Development" and "Logistics", which significantly affect the efficiency of technological management of the cluster. To improve the efficiency of technological potential realisation, it is appropriate to monitor the integral coefficient and partial coefficients characterising the realisation of technological potential within the innovation cluster and its individual components.

Analysis of the data of the surveyed innovation cluster indicates that in the period 2019-2021 the integral coefficient increased by 1.28%, including in 2020 the indicator decreased by 0.089% compared to the previous year, and in 2021, there was an increase of 2.19%. The best result was shown by the "Logistics" component, while "Personnel Development" showed the lowest. Such values of indicators are a consequence of the impact of the COVID-19 pandemic on business activity and innovation, but the trend is positive in 2021 there was an adaptation to the new functional environment, resulting in an increase in indicators.

The monitoring of the developed indicators will make it possible to assess the effectiveness of the realisation of technology management tools within the framework of the innovation cluster, which will allow for achieving better results in the process of post-war reconstruction of the country. However, the optimal combination of indicators that comprehensively characterise the efficiency of the implementation of technological potential can be the subject of further research.

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