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TECHNOLOGICAL MANAGEMENT OF INNOVATIONS IN LOGISTICS

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Abstract

The article considers the problems of development and assessment of technological management of innovations in logistics. It is determined that the system of indicators that are used for this assessment remains a controversial point in the assessment of technological management of innovations in logistics. An open question is also the selection of factors that can influence the effectiveness of technological management of innovations in logistics. On this basis, a methodology for assessing technological management of innovation in logistics is proposed. The methodology is developed using adaptive methods, the parameters of which change depending on changes in the real values of the indicator in a retrospective period, Brown's models and the method of the main modified component. This methodology will allow stakeholders to optimize logistics activities, plan the costs of such activities and diversify risks from such activities. A downward trend of innovations in logistics and their financing has been identified, which requires the formation of state support measures. The purpose of the article is to develop a methodology for evaluating the effectiveness of technological innovation management in logistics.

Keywords: *industrial enterprises, innovations, logistics, management, technologies, forecasting.*
JEL Codes: *L91, O31.*

Introduction

A turbulent external environment influences the current state of Ukraine's logistics system. Various environmental factors can have both negative and positive effects on logistics systems and innovation processes. The development of logistics and the transport sector in Ukraine is directly dependent on innovations and their support from the state. On the other hand, innovation depends on efficient logistics flows and transport hubs. In such an understanding, the importance of a timely assessment of innovations in logistics arises, which will allow a timely diagnosis of the needs and problems of this sector of the economy.

In addition, this diagnosis will reduce the negative impact of the external environment on logistics processes. The purpose of the article is to develop a methodology for evaluating the effectiveness of technological innovation management in logistics. The object of the study is the implementation of technological management in logistics.

Literature review

Technology management in logistics is a topical and important issue in the scientific circle of domestic and foreign scientists. Scientist (Potapova N., 2013) provides a system of indicators to assess innovation processes in Ukraine and determines the main directions of innovation policy in logistics systems. The author provides in detail the most effective ways of using innovations and technologies in modern logistics. The authors (Voronina R. et al., 2016) analysed the impact of technological innovations and the latest information technologies on the development of logistics in the short and long-term periods. Scientists have highlighted modern trends in logistics and the formation of new types and business models. Special attention was paid by the scholars to the advantages and disadvantages of the analysed innovations for logistics operators. In the article (Kostyuchenko L., 2016) the essence, problems and ways of solving the integration of innovative and strategic management of transport enterprise as an infrastructure element of the transport services market are investigated. Interesting for our study are works that highlight innovative approaches to the process of modelling complex economic systems and processes (Klochan I. et al., 2022; Khomiak N. et al., 2022; Aranchiy V. et al., 2022; Mazur N. et al., 2021; Telnova H. et al., 2022; Stolyarov V. et al., 2022; Sukhno V. et al., 2022; Vashchenko P. et al., 2022). The tools, logic of selection of indicators and methodology for describing the problems of the phenomenon being evaluated can be used to analyse the technological management of innovations in logistics. Scholars (Rejeb A. et al., 2021) rightly emphasise that the key drivers of innovative development are efficient logistics processes, which is why there is a need to monitor the current state of innovation and the complex of logistics systems. The authors (Bosona T. et al., 2013) have reviewed the logistics management in the agricultural food supply chain. This research is particularly important in the context of the issue of food security in a globalised world. Researchers (Zailani S. et al., 2014) investigated the background and outcomes of the implementation of environmental innovative technologies in transport companies in Malaysia. The authors conducted a questionnaire survey on the implementation of green technology innovation by Malaysian transport companies. The researchers found that the quality of human resources and environmental uncertainty have a significant impact on the environmental innovations of transport companies, while the influence of organisational and governmental support is negligible. In their article, the authors (Verhoeven P. et al., 2018) identified the typical cases of blockchain usage and analysed the usage of innovative technologies based on five principles. The authors identified the need to understand the problem and apply unique technologies to ensure efficiency and cost-effectiveness. Despite the considerable coverage of the issues of technological management of innovations in logistics, there is a need to deepen the tools for choosing a methodology for evaluating innovations in logistics processes.

Methodical approach

Before defining the methods needed for our study, let us define a system of indicators. In order to assess the technological management of innovation in logistics, a set of indicators $\{g_i\}_{i=1}^{6}$ has been used the list of which and their values during 2013-2020 are shown in Table 1.

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Table 1. Indicators for evaluating technological management of innovation in logistics

Indicator	Content of the indicator	Value of the indicator by years							
		2013	2014	2015	2016	2017	2018	2019	2020
g_1	Share of innovatively active enterprises in the total number of industrial enterprises, %	16,8	16,1	17,3	18,9	16,2	16,4	15,8	16,8
g_2	Share of enterprises that implemented innovations (including logistics and transport) in the total number of industrial enterprises, %	13,6	12,1	15,2	16,6	14,3	15,6	13,8	14,9
g_3	Number of implemented types of innovative products that can be used in logistics processes, total units	3138	3661	3136	4139	2387	3843	2148	4066
g_4	Number of innovative products implemented that are new to the logistics market, units	640	540	548	978	477	968	418	691
g_5	Number of new machines and equipment implemented that can be used in logistics	809	1314	966	1305	751	920	760	647
g_6	Share of innovative products sold in the total volume of products sold by industrial enterprises, %.	3,3	2,5	1,4	1,3	0,7	0,8	1,3	1,9

**Source: systematisation of indicators proposed by the authors.*

The dynamics of these indicators are characterised by frequent changes in the periods of growth and decline. For example, the chain growth rate of the number of implemented innovative products that can be used in logistics processes exceeded one in 2014, 2016, 2018 and 2020, while in 2015, 2017 and 2019 it was less than one. Another feature is the significant gap between the maximum and minimum values of these indicators during the selected retrospective period. Therefore, adaptive methods should be used to forecast the dynamics of these indicators, the parameters of which vary depending on the change in the real values of the indicator in the retrospective period. In this paper, the adaptive Brown's model is used to estimate the expected values of g_i indicators.

This model uses the function $G_i(t)=A_i(t)t+B_i(t)$, to determine forecast values, where t is the year number. As the information base for forecasting is statistical data for the retrospective period 2013-2020 and the forecast is determined for the years 2023 and 2024, the values of t variable from 1 to 12 correspond to the years 2013 to 2024. We denote the value of the g_i indicator, in t year by $g_i(t)$.

The values of the coefficients $A_i(t)$ and $B_i(t)$ for t=1 is determined from a system of equations:

$$\begin{cases} A_i(1)\sum_{t=1}^{5} t^2 + B_i(1)\sum_{t=0}^{5} t = \sum_{t=1}^{5} t g_i(t) \\ A_i(1)\sum_{t=1}^{5} t + 5B_i(1) = \sum_{t=1}^{5} g_i(t) \end{cases} \quad (1)$$

For the following values of t, the coefficients $A_i(t)$ and $B_i(t)$ are determined by the recurrence formulae:

$$\begin{aligned} A_i(t) &= A_i(t-1) + \beta^2(g_i(t-1) - G_i(t-1)) \\ B_i(t) &= A_i(t-1) + B_i(t-1) + \beta^2(g_i(t-1) - G_i(t-1)) \\ G_i(t) &= A_i(t)t + B_i(t) \end{aligned} \quad (2)$$

The last derived values $A_i(t)$ and $B_i(t)$ are used to calculate the forecast values. The parameter β is chosen empirically, i.e., among the models corresponding to different values of β, the one that gives the best forecasts for the years included in the retrospective period is selected.

Results

The results of applying Brown's model to predict the share of innovatively active enterprises in the total number of industrial enterprises are shown in Table 2.

The parameter β is assumed to be 0.1.

Table 2. Forecasting of the share of innovatively active enterprises (including logistics and transport) in the total number of industrial enterprises

Year	t	$g_i(t)$	$A_i(t)$	$B_i(t)$	$G_i(t)$	$g_i(t) – G_i(t)$
2013	1	16,8	0,16000	16,58000	16,74	0,06
2014	2	16,1	0,16540	16,74540	17,08	-0,98
2015	3	17,3	0,07754	16,82294	17,06	0,24
2016	4	18,9	0,09954	16,92248	17,32	1,58
2017	5	16,2	0,24168	17,16417	18,37	-2,17
2018	6	16,4	0,04615	17,21032	17,49	-1,09
2019	7	15,8	-0,05170	17,15862	16,80	-1,00
2020	8	16,8	-0,14140	17,01721	15,89	0,91
Forecast						
2023	11				15,46	
2024	12				15,32	

**Source: calculated by the authors.*

The current downward trend in the share of innovatively active enterprises is projected to continue in 2023-2024 but at a slower pace than from 2017 to 2020.

Similarly, projections for 2023 and 2024 are made for other innovative activity indicators. The results of the projections are presented in Table 3.

Table 3. Expected values of technology management evaluation indicators for logistics innovation in 2023 and 2024

Indicator	Content of the indicator	Expected values of the indicator	
		Year 2023	Year 2024
g_1	Share of innovatively active enterprises in the total number of industrial enterprises, %	15,46	15,32
g_2	Share of enterprises that implemented innovations (including logistics and transport) in the total number of industrial enterprises, %	14,53	14,48
g_3	Number of implemented types of innovative products that can be used in logistics processes, total units	2420	2360

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g_4	Number of new types of innovative products implemented that are new to the logistics market, units	707	710
g_5	Number of new machines and equipment implemented that can be used in logistics	641	610
g_6	Share of innovative products sold in the total volume of products sold by industrial enterprises, %	1,34	1,33

**Source: calculated by the authors.*

The results show that the share of enterprises that implement innovations (including logistics and transport) will slightly decrease in the forecast period compared to 2020 but will exceed the level of 2019. The number of implemented innovative products that can be used in logistics processes is expected to decrease significantly compared to 2020, but the value of this indicator will remain higher than in 2019. The number of innovative products implemented new to the market is forecast to increase compared to 2020 and the number of new machines and equipment Implemented is forecast to decrease. It is also projected that the share of sold innovative products in the total volume of sold products of industrial enterprises will decrease.

For a comprehensive assessment of technological management of innovations in logistics, we define an integral assessment that combines all the considered indicators. This assessment is defined by the equality:

$$W(t) = \sum_{i=1}^{6} \frac{\alpha_i (g_i(t) - g_i^{min})}{g_i^{max} - g_i^{min}} \qquad (3)$$

where g_i^{max} and $g_i^{min}$is, respectively, are the largest and the smallest value of indicator g_i during the retrospective period, and the coefficients α_i are chosen to ensure that the resulting integral score correlates most closely with all the scores g_i. We determine the coefficients, using the modified principal component method. To do this, we calculate the normalised values of $\overline{g_i(t)}$ of the indicators g_i by the formula:

$$\overline{g_\iota(t)} = \frac{g_i(t) - g_i^{min}}{g_i^{max} - g_i^{min}} \qquad (4)$$

We choose the coefficients, proportional to the coordinates of the eigenvector of the covariance matrix of the normalised indicators, which corresponds to the maximum eigenvalue of this matrix. The covariance matrix has the form:

	0,08674	0,12224	0,12008	0,12767	0,11060	0,05810
	0,06112	0,08252	0,07862	0,11138	0,04057	-0,01234
K =	0,05896	0,03931	0,12386	0,09891	0,05681	0,01901
	0,06654	0,07207	0,09891	0,12607	0,04474	-0,01836
	0,04948	0,00126	0,05681	0,04474	0,12504	0,01109
	-0,00302	-0,05166	0,01901	-0,01836	0,01109	0,10059

The maximum eigenvalue of this matrix λ^{max} = 0,3958, it corresponds to eigenvector A= {0,6008; 0,4224; 0,4108; 0,4616; 0,2712; 0,0721}.

Consequently, the integral assessment coefficients are as follows: α_1 = 0,36096; α_2 = 0,17842; α_3 = 0,16876; α_4 = 0,21307; α_5 = 0,07355; α_6 = 0,00520. The integral assessment values for the years of the retrospective period are determined according to the formula:

$$W(t) = 0{,}36096\overline{g_1(t)} + 0{,}17842\overline{g_2(t)} + 0{,}16876\overline{g_3(t)} + 0{,}21307\overline{g_4(t)} + +0{,}07355\overline{g_5(t)} + 0{,}00520\overline{g_6(t)}$$

The resulting values of the integral assessment of technological management of innovations in logistics are presented in Table 4.

Table 4. Integral assessments of technological management of innovations in logistics 2013-2020

Year	2013	2014	2015	2016	2017	2018	2019	2020
Estimation	0,36736	0,28674	0,46735	0,99497	0,18798	0,59188	0,08106	0,49630

**Source: calculated by the authors.*

To obtain the predicted value of the integral assessment, we use the obtained predicted values of the indicators g_i to calculate the corresponding normalised values $\overline{g_i(t)}$ at t=11 and t=12, which we substitute in the formula for determining the integral estimate W(t). We obtain a projected value of W(11)=0.1904 for 2023 and W(12)=0.1647 for 2024. The dynamics of the integral assessment of technological management of innovations in logistics during the retrospective period 2013-2020 and the forecast for 2023-2024 years are reflected in Figure 1.

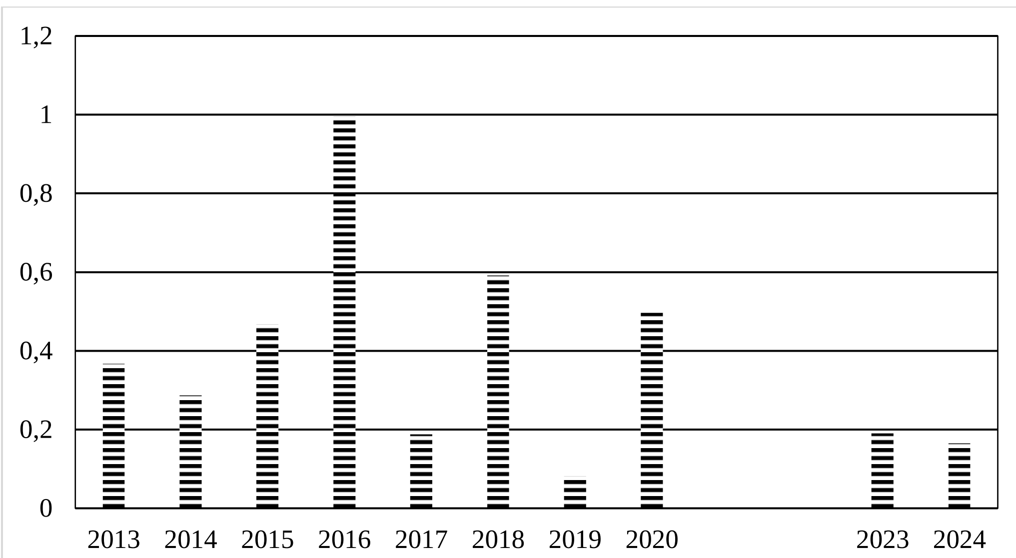

Figure 1. Integral assessment of technological management of innovations in logistics
**Source: calculated by the authors.*

Thus, forecasting the dynamics of technological management of innovations in logistics based on Brown's adaptive model shows a downward trend in the integral assessment of this activity compared to 2020 levels.

An important factor in the development of technological management of innovations in logistics is the funding of fundamental and applied scientific research aimed at the implementation of innovative technologies in logistics. A number of indicators have been used to assess the amount of funding for such research $\{q_i\}_{i=1}^{6}$, Table 5 provides a list of these indicators and their significance during the period 2013-2020.

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Table 5. Indicators for financing innovations in logistics

Indicator	Content of the indicator	Value of the indicator by years							
		2013	2014	2015	2016	2017	2018	2019	2020
q_1	Expenditures on innovations, UAH million	9562,6	7695,9	13813,7	23229,5	9117,5	12180,1	14220,9	14406,9
q_2	Expenditure on research and development, including logistics, UAH million	1638,5	1754,6	2039,5	2457,8	2169,8	3208,8	2918,9	3486,3
q_3	Expenditures on basic research, UAH million	2175	2200,8	2615,3	2698,2	2452	2460,2	2225,7	2924,5
q_4	Expenditures on applied research in logistics processes and sectors of the economy, UAH million	1589,4	1813,9	2023,2	2061,4	1882,7	1960,6	2561,2	3163,2
q_5	Expenditures on scientific and technical (experimental) developments required to improve logistics processes, UAH million	4342,7	4498,7	4781,4	5488,9	5152,8	6582,8	6743,8	7291,6
q_6	Share of expenditures on scientific research and development required to improve logistics processes in GDP, %	0,75	0,65	0,67	0,7	0,6	0,55	0,48	0,45

**Source: systematisation of indicators proposed by the authors.*

Between 2013 and 2015, these indicators (excluding the share of research and development expenditure in GDP) are increasing, with a significant decrease in 2017 and a renewed upward trend from 2018. The share of research and development expenditure on improving logistics processes in GDP has been decreasing since 2016. Brown's adaptive model has also been applied to predict the dynamics of these characteristics.

The function $Q_i(t)=L_i(t)t+M_i(t)$, where t is the year number, was used to determine the forecast values of indicator q_i. Years of the retrospective period from 2013 to 2020 correspond to the values of variable t from 1 to 8, and years of the forecast period (2023 and 2024) to the values t=11 and t=12, respectively. The value of indicator q_i in year t is denoted by $q_i(t)$. Values $L_i(t)$ and $M_i(t)$ for t>1 are determined from the following equations:

$$L_i(t) = L(t-1) + \beta^2(q_i(t-1) - Q_i(t-1))$$
$$M_i(t) = L_i(t-1) + M_i(t-1) + \beta^2(q_i(t-1) - Q_i(t-1)) \quad (5)$$

The results of applying Brown's model to forecast the costs of innovations and logistics processes are shown in Table 6. The parameter β is assumed to be 0,3.

Table 6. Forecasting the costs of innovations and logistics processes

Year	t	$q_i(t)$	$L_i(t)$	$M_i(t)$	$Q_i(t)$	$q_i(t) – Q_i(t)$
2013	1	9563	1464,340	8290,82	9755,16	-192,560
2014	2	7696	1447,010	9737,83	12631,8	-4935,949
2015	3	13814	1002,774	10740,6	13748,9	64,774
2016	4	23230	1008,604	11749,21	15783,6	7445,877
2017	5	9118	1678,733	13427,94	21821,6	-12704,104
2018	6	12180	535,363	13963,3	17175,5	-4995,384
2019	7	14221	85,779	14049,08	14649,5	-428,634
2020	8	14407	47,202	14096,28	14473,9	-66,998
Forecast						
2023	11				14615,5	
2024	12				14662,7	

**Source: calculated by the authors.*

Innovation and logistics process costs are projected to increase between 2023 and 2024 compared to 2020. Similarly, forecasts for 2023 and 2024 are made for other innovations financing indicators. The results of the projections are presented in Table 7.

Table 7. Expected values of indicators for financing innovative activity and logistics processes in 2023 and 2024

Indicator	Content of the indicator	Expected values of the indicator	
		Year 2023	Year 2024
q_1	Expenditure on innovations, UAH million	14615,5	14662,7
q_2	Expenditure on research and development, including in the area of logistics, UAH million	3662,11	3771,91
q_3	Expenditures on basic researches, UAH million	2271,81	2250,27
q_4	Expenditures on applied researches in logistics processes and economic sectors, UAH million	2936,69	3006,78
q_5	Expenditures on scientific and technical (experimental) developments required to improve logistics processes, UAH million	7626,07	7818,97
q_6	Share of expenditures on research and development required to improve logistics processes in GDP, %	0,416	0,398

**Source: calculated by the authors.*

The results show that research and development expenditures in logistics are expected to increase in the forecast period, but this increase will be achieved by a significant increase compared to 2020 in the costs of research and development (experimental), while the costs of basic and applied research and development will decrease. The share of research and development expenditure in GDP is also expected to decrease.

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To comprehensively assess the costs of innovative activity and logistics processes, we define a comprehensive integral estimate that combines all the indicators described above. This estimate is defined by the equality:

$$F(t) = \sum_{i=1}^{6} \frac{\eta_i (q_i(t) - q_i^{min})}{q_i^{max} - q_i^{min}} \quad (6)$$

where q_i^{max} and q_i^{min}, respectively, are the highest and lowest values of q_i during the retrospective period, and the coefficients η_i are chosen by the modified principal component method.

The normalised values of $\overline{q_i(t)}$ of the indicators g_i are determined from the equality:

$$\overline{q_i(t)} = \frac{q_i(t) - q_i^{min}}{q_i^{max} - q_i^{min}} \quad (7)$$

The covariance matrix of the normalised indicators is as follows:

K =

0,08520	0,03797	0,05705	0,02978	0,03565	-0,00051
0,03797	0,11928	0,06524	0,08233	0,12115	-0,09799
0,05705	0,06524	0,11111	0,06186	0,05718	-0,03504
0,02978	0,08233	0,06186	0,08840	0,08909	-0,08196
0,03565	0,12115	0,05718	0,08909	0,12665	-0,10636
-0,00051	-0,09799	-0,03504	-0,08196	-0,10636	0,10970

The maximum eigenvalue of this matrix λ^{max} = 0,4534, it corresponds to eigenvector A={ 0,185; 0,4968; 0,3283; 0,4045; 0,5122; 0,4304}. Consequently, the integral evaluation coefficients are as follows: η_1 = 0,03423; η_2 = 0,24681;

η_3 = 0,10778; η_4 = 0,16362; η_5 = 0,26235; η_6 = 0,18524. The integral estimation values for the years of the retrospective period are determined according to the formula $F(t) = 0{,}03423\overline{q_1(t)} + 0{,}24681\overline{q_2(t)} + 0{,}10778\overline{q_3(t)} + 0{,}16362\overline{q_4(t)} + +0{,}26235\overline{q(t)} + 0{,}18524\overline{q_6(t)}$;

The obtained values of the integral assessment of the costs for innovative activities and logistics processes are shown in Table 8.

Table 8. Integral cost estimates for innovative activities and logistics processes 2013-2020

Year	2013	2014	2015	2016	2017	2018	2019	2020
Estimation	0,18936	0,17993	0,35033	0,52431	0,30912	0,56027	0,52586	0,79535

**Source: calculated by the authors.*

The dynamics of the integral assessment of the costs of innovative activities and logistics processes over the retrospective period 2013-2020, together with the forecast for 2023-2024, is shown in Figure 2.

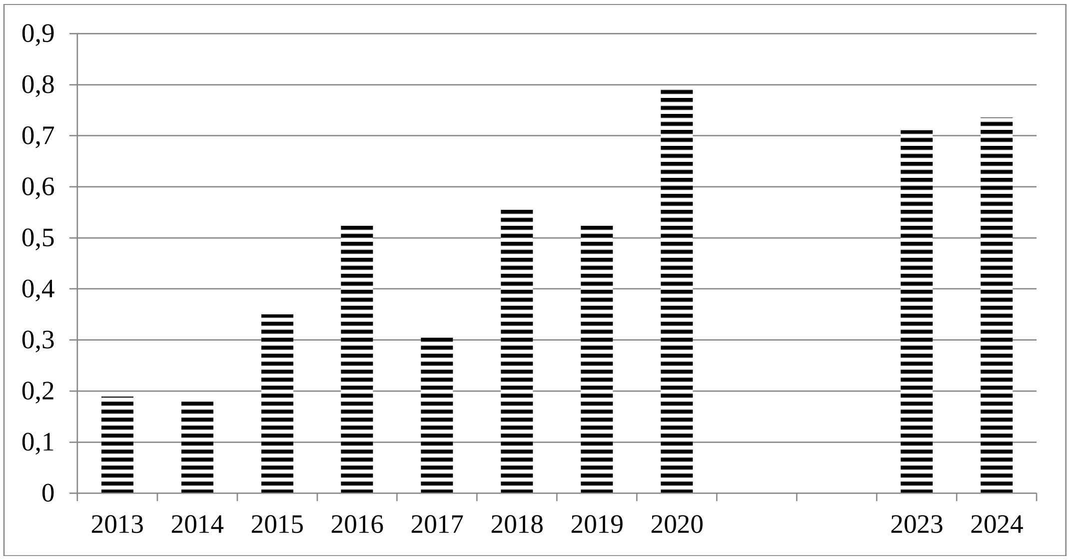

Figure 2. Integral assessment of the costs of innovative activities and logistics processes

**Source: calculated by the authors.*

There has been an upward trend in innovative activities expenditure since 2014. With the exception for 2016 and 2019, the integral estimate of innovative costs for logistics processes increases compared to the previous year and reaches a maximum value in the retrospective period in 2020. The projected value of the integral estimate F(t) for 2023 is 0.7106 and for 2024 - 0.7357. These estimates are lower than in 2020 but higher than in previous years of the retrospective period.

Conclusions

Thus, our study shows the problematics of a comprehensive assessment of technological management of innovations in logistics. It is established that during 2023-2024 the number of innovative enterprises implementing innovations in logistics will decrease. The number of innovative products implemented new to the market and the number of new machines and equipment implemented in the logistics sector is projected to increase compared to 2020. It is also projected that the share of innovative products sold in the total volume of industrial products sold will decrease. The results show that logistics research and development expenditure is expected to increase in the forecast period, but this increase will be driven by a significant increase compared to 2020 in research and development (experimental) expenditure, while fundamental and applied research and development expenditure will decrease. The above data indicate the need to intensify government activities to support innovations in logistics. Otherwise, it will not be possible to achieve proper technology development in logistics. The proposed methodology will be useful for use in the practical work of logistics companies, as well as enterprises that seek to introduce innovations in management. In addition, the methodology will allow public managers to analyze the state of technological management and innovations in logistics.

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