УДК: 330.341.1:656.96=811.111
https://doi.org/10.32342/3041-2137-2025-2-63-5

Oksana Karpenko,
Doctor of Sciences (Economics), Professor of Department of Management, Marketing and Public Administration, Academician Y. Bugay International Scientific and Technical University, Kyiv (Ukraine)
https://orcid.org/0000-0003-2943-1982

Olha Kravchenko,
Doctor of Sciences (Economics), Professor of Department of Finance, Accounting and Taxation, State University of Infrastructure and Technologies, Kyiv (Ukraine)
https://orcid.org/0000-0002-2258-2828

Olena Palyvoda,
Doctor of Science (Economics), Professor of Department of Management of Foreign Economic Activity of Enterprises, National Aviation University, Kyiv (Ukraine)
https://orcid.org/0000-0001-9714-9765

Svitlana Semenova,
PhD (Economic), Associate Professor of Department of Accounting and Taxation, State University of Trade and Economics, Kyiv (Ukraine)
https://orcid.org/0000-0001-7250-7482

EVALUATING THE EFFECTIVENESS OF INNOVATION IMPLEMENTATION AT TRANSPORT ENTERPRISES UNDER CONDITIONS OF UNCERTAINTY

In the conditions of economic uncertainty associated with war, the task of developing and applying new approaches to assessing the economic efficiency and feasibility of introducing innovations at transport enterprises has become more urgent. In the presented study, a mental model for the formation of the effects of innovations was developed based on scenarios that describe existing relationships and trends, with the aim of incorporating them into the planning of innovative activities at a transport enterprise using PJSC Ukrzaliznytsia as an example. The authors have demonstrated that, under current conditions, scenario modeling is advisable for forecasting innovative development. Based on the expert survey, a system of scenarios for the implementation of the innovative project was developed: «Innovative growth», «Insufficient demand», «Insufficient supply», «Resource conservation». The study evaluated the potential effectiveness of introducing innovations to improve transport (railway) infrastructure under the «Insufficient demand» and «Insufficient supply» scenarios for PJSC Ukrzaliznytsia. It was calculated that, under the «Insufficient demand» scenario, the efficiency of innovation would be negative but with a tendency towards further growth from -9.4% in 2025 to -11.8% in 2029. Under the «Insufficient supply» scenario, a negative result from the introduction of innovations was also obtained, but with a tendency to decrease from -0.4% in 2025 to -0.1% in 2029, which would lead to an increase in the level of transport demand from 76.81% in 2025 to 89.23% in 2029. It was determined that, under current conditions, the scenario «Insufficient supply» would be more effective as its implementation would ensure an increase in the level of satisfaction of transportation needs through increased funding for the innovative project. The analysis of scenarios showed that it is possible to reduce the probability of unwanted effects by implementing an effective planning system and using modern financing mechanisms for innovative activities of transport enterprises.

Keywords: innovation evaluation, innovation efficiency, uncertainty, transport, scenario modeling, homomorphism

JEL classification: ***C53, L92, R42***

В умовах економічної невизначеності, що пов’язана з війною, актуалізуються завдання розробки і застосування нових підходів до оцінювання економічної ефективності та доцільності впровадження інновацій на транспортних підприємствах.

У представленому дослідженні розроблено ментальну модель формування ефекту інновацій на основі сценаріїв опису існуючих взаємозв’язків та тенденцій з метою їх подальшого врахування при плануванні інноваційної діяльності транспортного підприємства на прикладі ПАТ Укрзалізниця. Авторами доведено, що у сучасних умовах для прогнозування інноваційного розвитку доцільно використовувати сценарне моделювання. На основі експертного опитування була розроблена система сценаріїв реалізації інноваційного проєкту («Інноваційне зростання», «Недостатній попит», «Недостатня пропозиція», «Ресурсозбереження»). У дослідженні оцінено можливу ефективність впровадження інновацій для покращення транспортної (залізничної) інфраструктури за сценаріями «Недостатній попит» та «Недостатня пропозиція» для ПАТ Укрзалізниця. Розраховано, що за сценарієм «Недостатній попит» ефективність інновацій буде негативною, але з тенденцією до подальшого зростання – від -9,4% у 2025 р. до -11,8% у 2029 р. За сценарієм «Недостатня пропозиція» було отримано також негативний результат від впровадження інновацій, але з тенденцією до зменшення з -0,4% у 2025 р. до -0,1% у 2029 р., що призведе до підвищення рівня транспортного попиту з 76,81% у 2025 р. до 89,23% у 2029 р. Визначено, що в нинішніх умовах сценарій «Недостатня пропозиція» буде більш ефективним, оскільки його реалізація забезпечить підвищення рівня задоволення потреби в перевезеннях за рахунок збільшення обсягу фінансування інноваційного проекту. Аналіз сценаріїв показав, що зменшити ймовірність виникнення небажаних ефектів можна шляхом впровадження ефективної системи планування та використання сучасних механізмів фінансування інноваційної діяльності транспортних підприємств.

Ключові слова: оцінювання інновації, ефективність інновацій, невизначеність, транспорт, сценарне моделювання, гомоморфізм

JEL classification: ***C53, L92, R42***

Introduction. Increased economic uncertainty associated with russian military aggression against Ukraine, destruction of transport infrastructure, destroying of vehicles and transport routes, lack of available financial resources for full recovery, social instability, etc. pose new challenges for scientists and practitioners to ensure the competitiveness and sustainability of the transport system, both in wartime and in post-war times. One of the ways to solve this problem is to focus transport enterprises on the introduction of the latest technologies that can simultaneously solve several problems: save all types of resources, meet demanding consumer demand, and guarantee environmental and military security.

Undoubtedly, the effective implementation of innovative technologies has a positive impact on the company’s efficiency, both current and future. However, an unsuccessful choice of innovation is always “expensive” for an enterprise, as it can lead to a loss of capital, promising opportunities, and most importantly, time as one of the development resources, which is especially dangerous in wartime.

Traditionally, innovations are characterized by a very high level of uncertainty, which is formed by technical, technological and commercial components. In wartime, the uncertainty of the business environment multiplies. This directly affects the possibility of obtaining verified assessments of innovations in terms of their economic feasibility. The consequences of this are the inability to accurately predict the timing of achieving the goals and risks of an innovation project, and to obtain reliable forecasts of future costs and revenues associated with its implementation. In addition, the vast majority of innovation assessment methods and models are based on assumptions about the stationarity and predictability of processes in the internal and external environment of an enterprise, which does not allow the use of correlation and regression analysis methods for forecasting and planning in modern conditions.

In connection with the above, the tasks of developing and applying new approaches to assessing the economic efficiency and feasibility of introducing innovations at transport enterprises under conditions of uncertainty are becoming more relevant.

Literature review. The analysis of scientific research is showed that Data Envelopment Analysis (DEA) is a widely used method of analyzing the effectiveness of innovations in the world practice. This is a non-parametric method of operations research that allows measuring the relative efficiency of a certain group of homogeneous decision-making units. Its advantage is that it helps to compare objects for which there are no market prices and which are represented in different units and on different scales. This method is widely used to evaluate the innovation process both at the national level and at the level of individual entities [1-2]. Research is devoted to the development of methods for measuring the efficiency of processes in industry [3-4].

In particular, the study of the global innovation efficiency of the EU member states and candidate countries based on the Global Innovation Index (GII), as well as the Data Envelopment Analysis (DEA) and Efficiency Analysis Technique with Input and Output Satisficing (EATWIOS) methods, is devoted to the study of Turkish scientists Ahmet Aytekin, Fatih Ecer, Selçuk Korucuk and Çağlar Karamaşa. According to their study, the most effective countries in terms of global innovation efficiency are the Netherlands, Germany, and Sweden [5].

With the advent of the green economy, special attention is being paid to assessing the effectiveness of environmental innovations. In particular, Li Qinyang proposed to analyze regional technological innovation and green economy efficiency based on the DEA model and fuzzy estimation. The results of his study are showed that the Slacks-Based Measure of Efficiency (SBM) model increases the accuracy and reliability of assessing the economic efficiency of green innovations [6].

S. Fang and his colleagues proposed to evaluate innovations based on Tobit regression and Data Envelopment Analysis (DEA). In this way, they analyzed the innovation efficiency of 23 enterprises from 2013 to 2018 and built a structure for assessing the effectiveness of technological innovations for these enterprises [7].

Today, open innovations occupy a special place in high-tech companies. The study of Glenn P. Carroll and his colleagues is devoted to the assessment of their effectiveness. In particular, they proposed to use a dashboard that includes quantitative and qualitative elements to improve decision-making efficiency [8].

A number of researchers propose their own indicators of innovation effectiveness. For example, I. Ansoff proposed an innovation quality indicator based on assessing the probability of success in the final development of innovations, successful implementation of innovations in the market segment, successful implementation of an innovative product, technical, technological and economic characteristics of an innovation [9]. However, this indicator is mainly used to evaluate marketing innovations. In addition, it is based on estimates of the probabilities of various aspects of the innovations' "success", which is extremely difficult and sometimes impossible to assess before their implementation.

There is also an approach in the scientific literature that considers innovations as one of the manifestations of the company's investment activity. That is why it is believed that the indicators used to justify the economic efficiency of investment projects can be used to assess their effectiveness, namely indicators that do not consider the time factor and are based on accounting estimates (Undiscounted Payback Period, Accounting

Rate Of Return, Economic Value Added) and indicators whose calculation involves discounting the income and expenses associated with the project (Net Present Value, Profitability Index, Internal Rate of Return, Discounted Periodic Rate of Return, Discounted Periodic Rate of Return) [10].

Some studies are proposed using a scoring approach to determine the effectiveness of innovations and innovation projects. According to this approach, the assessment is based on the total number of points accrued at different stages of the innovation effectiveness assessment and weighted by coefficients. However, when implementing this approach, there are problems with determining certain indicators that characterize an innovation project, such as the total capacity of intellectual property in an innovation project, its labor intensity, budget efficiency, profitability, etc. [11].

The intensity of changes in the external environment and their impact on the innovation activities of companies, in particular transport, significantly affect the list of methods and models that should be used to evaluate innovation projects. In the context of increasing instability, qualitative approaches to analyzing future trends in the development of companies, in particular the scenario approach, gain significant advantages by considering potential changes in their external and internal environment, as well as reducing the impact of risk situations on the final efficiency [12].

Selection of previously unsolved parts of the overall problem. Emphasizing the significance of the Ukrainian and foreign researchers' scientific work, it should be noted that the problem of assessing the effectiveness of innovation at transport enterprise remains relevant and requires further development, since the modern economic environment has faced new challenges that have deepened instability due to the emergence of a large number of additional factors (geopolitical, military, pandemic, market, energy, technological, institutional, etc.), that affect business operations and are poorly predictable.

The purpose of the article. The purpose of this study is to develop a mental model illustrating how the effects of innovation are formed, using scenario analysis to describe existing relationships and emerging trends. This model aims to support the planning of innovation activities in transport enterprises, using JSC Ukrzaliznytsia as a case study.

Research objectives: (1) to formulate theoretical principles and substantiate the homomorphism apparatus for implementing a scenario approach to assessing the effect of innovation at a transport enterprise; (2) to build a model of the economic efficiency formation of innovation at JSC Ukrzaliznytsia; (3) to develop and evaluate a system of scenarios for the implementation of an innovative project to improve a section of transport (rail) infrastructure for JSC Ukrzaliznytsia.

The main research results. The high riskiness of innovation activities and limited financial resources actualize the problem of choosing the optimal innovation solution, which involves a correct assessment of the results of innovations, their impact on the current and future activities of the enterprise. The effects of innovations are heterogeneous, and scholars do not have a consensus on their qualification. The study shows that various effects of innovations should be considered, but for a transport enterprise the most important is the economic effect [13]. In this context, the problem of determining the moment that can be considered the beginning of innovation is of particular importance. One of the main features of the innovation implementation at transport enterprises is that, at each individual enterprise, innovations are most often implemented in the diffusion phase and, accordingly. As a result, there is already some information available about their implementation at similar enterprises, both domestically and abroad. In addition, the effectiveness of innovations and investments is significantly influenced by the ability of employees to implement them effectively, i.e., the availability of certain experience is assumed. This allows us to use analogs to assess the effectiveness of innovations.

The effect of innovation can be represented by the following formula:

$$e_{In,i} = e_{In,i}^{pri} + e_{In,i}^{in} + e_{In,i}^{pr}, \qquad (1)$$

where $e_{In,i}$ – total effect of the introduction of the i-th innovation;

$e_{In,i}^{pri}, e_{In,i}^{in}, e_{In,i}^{pr}$ – effect from the introduction of the i-th innovation, which is formed at the pre-investment (assessment of the possibility and feasibility of introducing an innovation at a transport enterprise), investment (investment in the actual implementation of the innovation) and production (production and sale of innovative products) phases.

The effect of innovation in the pre-investment phase will be manifested, on the one hand, through the parameters characterizing the success of research on the possibility and feasibility of introducing this innovation into the activities of a transport enterprise and, on the other hand, through hypothetical (forecast) estimates of production, economic and financial indicators. The reliability of hypothetical estimates will be directly influenced by the set of methods and models used for forecasting, the qualifications of personnel, and the existing financial constraints on the costs of conducting pre-investment research. Thus, the higher the qualification of the staff and the greater their awareness of modern forecasting approaches and the feasibility of their use under the existing level of uncertainty, provided that financial resources are sufficient, the greater the likelihood of obtaining verified forecast quantitative and qualitative characteristics related to the introduction of innovations. At the same time, it will be more likely that these characteristics will change in the future within the specified limits, which will facilitate the planning of the enterprise's activities. Then the model of formation of the effect of implementing the i-th innovation in the pre-investment phase can be represented as follows:

$$e_{In,i}^{pri} = \left[\varphi_i^{pri}: M_i \times S_i \times K_i \times F_i \to PE_i^{pri}\right], \qquad (2)$$

where $M_i M_i$ – the set of forecasting methods used to assess the feasibility of implementing the i-th innovation;

S_i – the set of specialists involved in assessing the feasibility of implementing the i-th innovation;

K_i – the set of competencies of the company's specialists;

F_i – costs (available financial resources) for the evaluation of the i-th innovation;

φ_i^{pri} – the emergence relation, which is realized on the sets M_i, S_i, K_i, by considering the amount of costs for assessing the feasibility of implementing the i-th innovation (F_i);

PE_i^{pri} – the set of production, economic and financial parameters of the i-th innovation, which are determined within the existing limitations of the implementation of the sets M_i, S_i, K_i and the amount of costs F_i and are the estimated parameters of the i-th innovation.

The investment phase of innovation implementation involves the cost of creating production facilities that will be used in the provision of transportation services and, as a result, will be a factor in the formation of estimated revenues. The costs of implementing innovative technologies include detailed design, purchase and installation of equipment, etc. Funds for these purposes are allocated on the basis of research that is traditionally conducted in the pre-investment phase.

Two assumptions are made for further research.

Assumption 1. Strict adherence to the technical, financial, economic and time conditions determined in the pre-investment phase during the investment phase allows achieving the planned levels of production, economic and financial indicators with a high probability when implementing the i-th innovation.

Assumption 2. The amount of costs for the implementation of the investment phase of innovations may, if necessary, change within certain limits to adapt to changing conditions.

Then, considering the assumptions made, the model of the effect of the introduction of the i-th innovation in the investment phase can be presented as follows:

$$e_i^{in} = \left[\varphi_i^{in}: Z_i \times T_i \to PE_i^{in}\right], \qquad (3)$$

where Z_i – the planned cost of creating production facilities for the *i*-th innovation;

T_i – the planned period of time for the implementation of the investment phase of the *i*-th innovation;

φ_i^{in} – the emergence ratio, which is realized on the planned cost of creating production capacities (Z_i) and the time of implementation of the investment phase of the implementation of the *i*-th innovation (T_i);

PE_i^{in} – the set of production, economic and financial parameters of the *i*-th innovation, which are determined within the existing constraints of the planned costs Z_i i and the time period T_i.

It should be considered that, unlike the pre-investment and investment phases, which involve only expenses (outgoing cash flow), the production phase will generate both outgoing and incoming cash flows. Therefore, one of the main tasks of the production phase for transport enterprises will be to maximize profits. In this case, the model of formation of the effect from the introduction of the *i*-th innovation in the production phase can be represented as follows:

$$e_i^{pr} = \left[\varphi_i^{pr} : X_i \times U \times IM^{env} \rightarrow PE_i^{pr}\right], \qquad (4)$$

where X_i – the set of project services that will be provided as a result of implementing the *i*-th innovation;

U – the set of parameters of the enterprise management system;

IM^{env} – the set of positive and negative environmental influences;

φ_i^{in} – the emergence relation, which is realized on the sets X_i and IM^{env} considering the peculiarities of the enterprise management system (U);

PE_i^{in} – the set of economic and financial parameters that characterize the efficiency of the enterprise.

Thus, model (1)-(4) describes the formation of the innovation effect of at different stages of the investment cycle.

When assessing the feasibility of introducing a particular innovation, the experience of implementing innovations at this or similar enterprises should be used through the creation of analogues. This makes it possible to use the appropriate mathematical apparatus, namely the concepts of homomorphism and isomorphism, which allow establishing the degree of correspondence between the system under study and the model. Thus, V. Tomashevsky notes that a system and a model are isomorphic to each other if there is a mutually unambiguous correspondence between them. This allows for transforming one representation into another. When simplifying a system (reducing the properties and characteristics that are considered when building model structures to describe system states), the closeness of the relationship between the system and the model is reduced, i.e., homomorphic relationships are formed that determine an unambiguous correspondence in only one direction - from the model to the system [14]. When building models of complex systems or processes, such as innovation, it is extremely rare to ensure complete isomorphism. This is due to, on the one hand, the inability to consider absolutely all the characteristics of the system, its internal and external relations and, on the other hand, the excessive size and complexity of the model built, which will create difficulties in its practical use. Therefore, it is advisable to simplify the system under study by applying to it only a one-way transformation from model to system, which leads to the use of homomorphic mappings. Given the above, an additional assumption is added to build the model.

Assumption 3. For each innovation project that has been implemented or is being implemented at the enterprise, information data is stored on the effect obtained at all stages of project implementation.

The use of the homomorphism apparatus allows the use of a scenario approach to obtain estimates of the effect of innovation at the enterprise. The assumptions made will have a real basis in connection with the creation of a database that stores models of all subject areas created and implemented both in the pre-investment and investment and production phases. To obtain a sufficient degree of homomorphism of the model when using the scenario approach, it is possible to organize an expert survey of leading specialists of transport enterprises and scientists dealing with the innovation's problems. This will allow to obtain sufficiently verified estimates of a particular innovation, on the basis of which scenarios of its possible implementation will be developed and the expected effects will be assessed. Fig. 1 shows the schematic diagram of the use of the similarity apparatus (homomorphism) to assess the effectiveness of innovation implementation at transport enterprises.

The introduction of innovations involves analyzing their implementation in the future. This necessitates the use of forecasting methods that would adequately consider the current and future uncertainty of the external environment at the transport enterprise. In conditions of high uncertainty, traditional forecasting methods, as mentioned earlier, cannot be used. In addition, one of the peculiarities of innovations is that there is usually no experience in their implementation. Transport enterprises have some experience in implementing similar investment projects. In particular, the largest share of their innovation expenditures is allocated to the purchase of machinery, equipment, and software [15]. It should also be noted that transport enterprises use very specific equipment and technologies that depend on the type of transport to which they belong. This enables the use of the similarity apparatus to analyze and assess the feasibility of introducing innovations (homomorphism) and leads to the application of qualitative methods for researching the future.

Since there is no reliable data on the potential effectiveness of innovations at the time of their introduction, but there is information on the implementation of similar investments and experts capable of providing informed opinions, forecasting should be based on expert surveys as a key element in building an information base for scenario modeling.

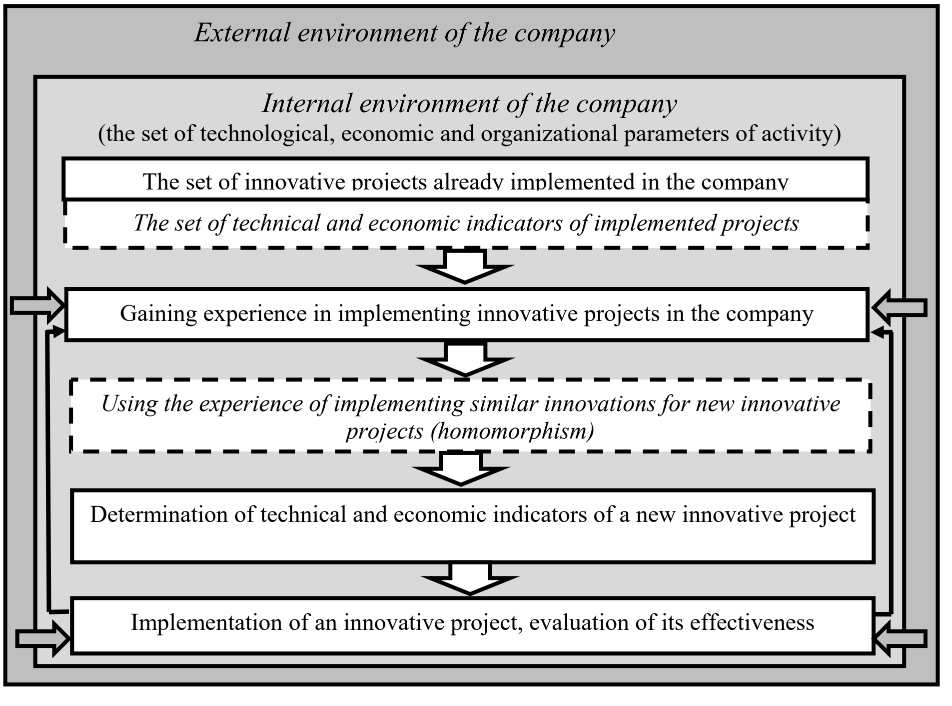

Fig. 1. The schematic diagram of using the similarity apparatus (homomorphism) to assess the effectiveness of innovation implementation at transport enterprises
Source: created by the authors

Scenario modeling is one of the modeling approaches that considers several alternative options for the development of a particular process or system. In conditions of increased uncertainty, scenario modeling is one of the most effective tools for strategic management [16]. It involves structuring a wide flow of information about the process (object) under study, which allows identifying a limited set of internal and external environment factors (key uncertainties) that may have a decisive impact on the development of the process (innovation implementation) in the future. In the process of scenario modeling, ideas about possible future developments are organized.

When building scenarios, it is necessary to consider the factors that will determine the final effectiveness of innovation. Such factors can be considered as drivers (key uncertainties) of innovation efficiency growth. To identify the key uncertainties that will determine the attractiveness of innovations for rail transport enterprises, an expert survey is conducted among specialists and scientists involved in the development of rail and other modes of transport. A total of 20 people are involved and are presented with a questionnaire containing 12 factors. The assessment of the experts' professionalism showed that they are sufficiently competent specialists in the area, with competence levels ranging from 0.593 to 0.824). The consistency of opinions is assessed using the Kendall's concordance coefficient, which was 0.728, indicating an average degree of consistency. This result is expected due to the composition of the expert group. The reliability of the concordance coefficient is assessed using Pearson's criterion, which was 160.16. For a significance level of 0.05 and 11 degrees of freedom, the normative value of $\chi^2 \chi^2$ was 19.675. This indicates that the null hypothesis of randomness of the coherence of expert opinions should be rejected, and the obtained results are reliable.

The conducted expert survey showed that, given the current situation in Ukraine and the world, the key uncertainties for transport enterprises will be (1) the need (mandatory) to introduce innovations; (2) the situation in the country (the intensity of military operations in Ukraine). In order to formulate possible scenarios for the introduction of innovations, we have identified possible positive and negative realizations of these key uncertainties.

The first key uncertainty is the need to implement innovations. Implementation of innovations is one of the main conditions for the development of any enterprise, including transport enterprises. Since the technological lag of rail transport is 1-2 generations, innovations are now a factor for JSC Ukrzaliznytsia to get closer to European transportation standards in terms of speed and quality. Therefore, it makes sense to consider two alternatives for its implementation. The positive alternative is that the company's management is aware of the need to introduce innovations, thereby creating a demand for research and development of equipment and technologies adapted to the Ukrainian and European transportation networks. The negative alternative is to maintain the current state, i.e., the actual absence of innovations. The main indicators that will characterize the realization of the first key uncertainty are the amount of planned research and development work and the financial resources available for implementing innovative equipment and technologies.

The second key uncertainty is the situation in the country, specifically the intensity of military operations in Ukraine. A full-scale military invasion is currently underway, and its duration and intensity directly affect all processes within the country. A positive alternative would be a rapid end to the hot phase of the war (2024-2025), which would allow for the recovery of all sectors of the Ukrainian economy, providing an additional impetus for the innovative development of transport, including rail transport. Conversely, a negative alternative is the prolongation of the hot phase of the war, which would lead to further destruction of transport infrastructure and the formation of insufficient financial resources for innovation. The main indicators that will characterize the realization of the second key uncertainty will be the need for rail transportation and the capacity of the rail infrastructure.

In scenario modeling, it is also necessary to identify the factors that will form an unchanging basis for the implementation of any scenario of innovation activity of a transport enterprise, namely the predictable elements. For JSC Ukrzaliznytsia, one such predictable element is the technological features of rail transport, which include the presence of a developed transport infrastructure (rail transport network), as well as the high interdependence of transport infrastructure, vehicles (rolling stock) and transportation technologies. A schematic diagram of scenario modeling for assessing the effectiveness of innovation at rail transport is shown in Fig. 2.

Based on the identified key uncertainties for JSC Ukrzaliznytsia, four scenarios for the implementation of innovations at the transport enterprises are identified. The scenarios are built by sequentially combining positive and negative key uncertainties, taking into account the immutability of the assumed element.

Scenario 1: "Innovative growth". This scenario assumes a combination of favorable outcomes for key uncertainties – specifically, that the introduction of innovations will enable the enterprise to reach a qualitatively new level in the development of rail transport. This progress would be accompanied by the emergence of innovative products (services or works) that meet sufficient market demand. It can be considered an optimistic scenario, as its implementation would result in the maximum possible benefit for the transport company from innovation adoption. However, in this situation, this scenario has a low probability of realization, since the vast majority of experts, both Ukrainian and foreign, believe that military operations will not cease in 2025.

Scenario 2: "Insufficient demand". This scenario will be realized if the first key uncertainty is positively realized (i.e., obtaining a new quality in the operation of the enterprise), but there is no demand or insufficient demand for innovative products in the market to generate the expected profit – either due to the continuation of the hot phase of the war or the disruption

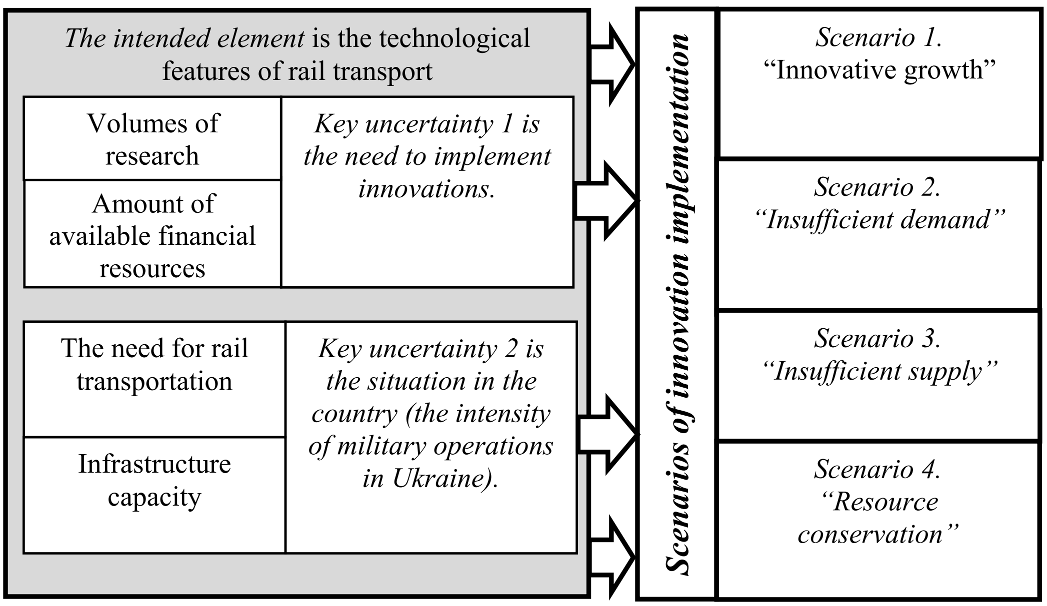

Fig. 2. Schematic diagram of scenario modeling for assessing the effectiveness of innovation implementation at rail transport

Source: developed by the authors

of the rail transport network caused by its destruction. In this case, there will be a loss of financial and non-financial resources of JSC Ukrzaliznytsia, as the innovation will not achieve the required economic effect.

Scenario 3: "Insufficient supply". This scenario will be implemented if the implementation of the innovation does not lead to qualitative changes at the enterprise, and the market will see an increase in demand for rail transportation (positive alternative of the key uncertainty 2). In this case, JSC Ukrzaliznytsia will lose the opportunity to increase both its level of development and potential efficiency.

Scenario 4: "Resource conservation". This scenario assumes the implementation of negative alternatives to key uncertainties, i.e., the transport company will not implement the innovation in the absence of market demand. In this case, the transport company does not waste resources and does not lose potential profits. This will save limited resources for other innovations.

These scenarios have different probabilities of realization. Thus, according to the surveyed experts, the current probability of implementing scenario 1 – "Innovative growth" – is 0.05-0.1, which is primarily due to the difficult financial condition of JSC Ukrzaliznytsia and the low investment attractiveness of rail transport in general. This will not allow the attraction of significant amounts of funds from private investors for the company's innovative development. The probability of scenario 2 – "Insufficient demand" – is estimated at 0.40-0.45, which is associated with a decrease in demand for rail transportation. The probability of scenario 3 – "Insufficient supply" – is estimated at 0.45-0.50, which is associated with high inertia of innovative development of rail transport infrastructure, especially with a significant shortage of available financial resources. The probability of realization of scenario 4 – "Resource conservation" – is estimated at 0.00-0.05. Thus, for the identified key uncertainties, only scenarios 2 and 3 have a significant probability. For these scenarios of innovation implementation in JSC Ukrzaliznytsia, calculations are performed in MS Excel using adaptive forecasting methods, in accordance with formulas (1)–(4), for an innovation project aimed at improving a section of transport infrastructure that is of strategic importance for the national economy and for ensuring Ukraine's security and defense capabilities. This section is located in the western part of Ukraine, and its role as a component of the country's humanitarian logistics has increased significantly since the outbreak of hostilities. This section of the transport infrastructure connects the logistics hub created after the start of the russian federation's full-scale military aggression against Ukraine with the main rail transport network.

One of the main goals of the innovations is to increase the capacity of the transport infrastructure section (rail transport network) by introducing the latest equipment and technologies to improve tracks and traffic management (signaling, centralization and blocking devices). This will increase the volume of transportation on this section and improve its speed and quality. It is expected that these innovations will be financed through grant funding from the Trust Fund for Support, Recovery, Rehabilitation and Reform of Ukraine with the support of the Government and funds from JSC Ukrzaliznytsia. The calculations are made based on the forecasts of the Cabinet of Ministers of Ukraine and experts of JSC Ukrzaliznytsia regarding the volume of freight and passenger rail transportation.

Such innovations (improvements to sections of the rail transport infrastructure network) have been repeatedly implemented by JSC Ukrzaliznytsia, so the homomorphism apparatus described earlier can be used to predict the main parameters of the innovation project.

In order to prevent data leakage regarding the location of this section of the transport infrastructure and the actual and forecast parameters of transport operations on it, the study presents artificial data while maintaining the actual trends for the period of 2025-2029.

Table 1 shows the calculations of the effectiveness of the scenario for implementing the innovations in JSC Ukrzaliznytsia to improve the transport (rail) infrastructure section. For the calculations, artificial data on the need for transportation and the capacity of the transport (rail) infrastructure section are used to prevent data leakage on the functioning of the strategic transport enterprise under martial law in Ukraine. The trends in the indicators used have been maintained. Optimistic and pessimistic estimates of changes in the need for transportation and capacity have been made by the specialists of JSC Ukrzaliznytsia.

As can be seen from the above calculations, the implementation of the "Insufficient demand" and "Insufficient supply" scenarios will result in a negative effect from the introduction of innovations. In the "Insufficient demand" scenario, the effectiveness of innovations will be negative with a tendency to further growth - from -9.4% in 2025 to -11.8% in 2029.

This result will be obtained as a result of an increase in the capacity of the section with a decrease in demand for transportation, while the necessary work will be 100% funded. In the "Insufficient supply" scenario, a negative result from the introduction of innovations will also be observed, but it will decrease from -0.4% in 2025 to -0.1% in 2029. This will increase the level of transportation demand from 76.81% in 2025 to 89.23% in 2029. Thus, under current conditions, the "Insufficient supply" scenario can be considered as optimistic.

One of the advantages of the scenario approach is that, based on the analysis of the developed scenarios, it is possible to develop measures to prevent or reduce the negative impact of various factors on the implementation of the processes under study, including the introduction of innovations at transport enterprises. The analysis of the scenarios shows that it is possible to reduce the likelihood of undesirable (unexpected) effects by introducing an effective planning system and using modern mechanisms for financing the innovative activities of transport enterprises, in particular, JSC Ukrzaliznytsia.

Table 1

Calculation of key indicators of an innovative project to improve a section of rail infrastructure under certain scenarios

Indicators	Years of implementation				
	2025	2026	2027	2028	2029
Scenario "Insufficient demand"					
Demand for transportation, million tons	1,26	1,22	1,18	1,12	1,04
Transportation capacity, million tons	1,32	1,39	1,46	1,54	1,58
Current satisfaction of the need for transportation, %	104,67	113,08	124,04	138,27	151,65
Possible amount of financing, %	100,00	100,00	100,00	100,00	100,00
Revenue growth rate, %	-4,04	-4,16	-4,29	-4,41	-4,55
Expenditure growth rate, %	5,31	5,73	6,19	6,69	7,22
Efficiency of innovations, %	*-9,4*	*-9,9*	*-10,5*	*-11,1*	*-11,8*
Scenario "Insufficient supply"					
Demand for transportation, million tons	1,93	1,98	2,04	2,14	2,17
Transportation capacity, million tons	1,48	1,58	1,69	1,81	1,94
Current satisfaction of the need for transportation, %	76,81	79,95	83,05	84,63	89,23
Possible amount of financing, %	59,04	67,90	78,08	89,79	100,00
Revenue growth rate, %	2,69	3,31	3,87	4,53	5,30
Expenditure growth rate, %	3,10	3,47	4,03	4,67	5,42
Efficiency of innovations, %	-0,4	-0,2	-0,2	-0,1	-0,1

Source: calculated by the authors

Conclusions. One of the challenges in implementing innovations is the lack of experience, which makes it difficult to assess the feasibility of their realization. It is shown that transport enterprises have some experience in implementing similar investment projects due to the specifics of the equipment and technologies they use. This made it possible to apply the apparatus of similarity (homomorphism) to assess the feasibility of innovations at transport enterprises, thereby enhancing the reliability of the estimates regarding the expected effects of their implementation at these enterprises.

It is substantiated that in modern conditions it is advisable to use scenario modeling for forecasting. To identify the factors that will influence the effectiveness of innovation at transport enterprises, an expert survey was conducted, based on which the key uncertainties (the need for innovation and the situation in the country, particularly, the intensity of military operations in Ukraine) were identified. Based on these, a system of scenarios for the implementation of an innovation project is developed: "Innovative growth", "Insufficient demand", "Insufficient supply", and "Resource conservation". For the "Insufficient demand" and "Insufficient supply" scenarios, the possible effectiveness of introducing innovations to improve the transport (rail) infrastructure, are assessed. It is determined that in the current conditions, the "Insufficient supply" scenario will be more effective, as its implementation will ensure an increase in the satisfaction of the need for transportation due to an increase in the amount of funding for an innovative project. The analysis of the scenarios shows that it is possible to reduce the likelihood of undesirable effects by implementing an effective planning system and using modern mechanisms for financing the innovative activities of transport enterprises.

References

1. Durana, P., Zauskova, A., Vagner, L., Zadnanova, S., (2020). Earnings Drivers of Slovak Manufacturers: Efficiency Assessment of Innovation Management. *Applied Sciences*. 10(12):4251. https://doi.org/10.3390/app10124251

2. Nicole, Adler, Lea, Friedman, Zilla, Sinuany-Stern (2002). Review of ranking methods in the data envelopment analysis context, European Journal of Operational Research, Vo140(2), pp. 249-265.

3. Palyvoda, Olena, Plavan, Viktoriya. (2016). Assessment of synergies in forming of cluster organizational structures. Economic Annals-XXI, 158(3-4), pp.48-51

4. Hollanders, Hugo & Esser, Funda. (2007). Measuring innovation efficiency. Economic Theory - ECON THEORY.

5. Ahmet, Aytekin, Fatih, Ecer, Selçuk, Korucuk, Çağlar, Karamaşa. (2022). Global innovation efficiency assessment of EU member and candidate countries via DEA-EATWIOS multi-criteria methodology, Technology in Society, no 68, pp.101-896 https://doi.org/10.1016/j.techsoc.2022.101896.

6. Li, Qinyang (2019). Regional Technological Innovation and Green Economic Efficiency Based on DEA Model and Fuzzy Evaluation. Journal of Intelligent & Fuzzy Systems, vol. 37, no. 5, pp. 6415-6425. DOI: 10.3233/JIFS-179220

7. Fang, S., Xue, X., Yin, G., Fang, H., Li, J., Zhang, Y. (2020). Evaluation and Improvement of Technological Innovation Efficiency of New Energy Vehicle Enterprises in China Based on DEA-Tobit Model. *Sustainability*, 12(18):7509. https://doi.org/10.3390/su12187509

8. Glenn, P., Carroll, Sanjay, Srivastava, Adam, S., Volini, Marta, M. Piñeiro-Núñez, Tatiana, Vetman (2017). Measuring the effectiveness and impact of an open innovation platform, Drug Discovery Today, vol. 22, no 5, pp. 776-785, https://doi.org/10.1016/j.drudis.2017.01.009.

9. Ansoff, I., Kipley D., Lewis, A., Helm-Stevens, R., Ansoff, R. (2019). Implanting strategic management. New York: Palgrave Macmillan, 611 p.

10. Pukhalska, N.O., Honcharenko, L.M. (2018). Suchasnyi stan innovatsiinoi diialnosti vitchyznianykh promyslovykh pidpryiemstv. [The current state of innovative activity of domestic industrial enterprises]. Ekonomika ta upravlinnia pidpryiemstvamy. no 20. pp. 113–118.

11. Rud? N. (2018). Systematyzatsiia metodychnykh pidkhodiv shchodo otsiniuvannia efektyvnosti innovatsiinykh proektiv. [Systematization of methodological approaches for evaluating the effectiveness of innovative projects]. Ekonomichnyi chasopys Skhidnoievropeiskoho nats. un-tu im. Lesi Ukrainky. Rozdil III. Ekonomika ta upravlinnia pidpryiemstvamy. no 1. pp. 55–62.

12. Kravchenko, O., (2020). Scenario Analysis of the Assessment of the Rail Transport Impact on the Economic Growth (on the Example of Ukraine). Economic Studies journal, no 1, pp. 114–135

13. Lysenko, L.A. (2007). Pidkhid do otsinky efektyvnosti innovatsiinoi diialnosti pidpryiemstva.[An approach to the evaluation of the efficiency of the enterprise's innovative activity]. Komunalne hospodarstvo mist. Kyiv: «Tekhnika», no 78. pp. 94–100

14. Tomashevskyi? V.M. (2005). Modeliuvannia system [Modeling of systems]. Kyiv: Vydavnycha hrupa «BHV», P. 332.

15. Kukushka, I.V. (2022). Innovatsiinyi rozvytok transportnykh pidpryiemstv Ukrainy [Innovative development of transport enterprises of Ukraine]. Ekonomika ta suspilstvo, no 43. pp. 118-128.

16. Kravchenko, O., Bohomolova, N., Karpenko, O., Savchenko, M., Bondar, N. (2020). Scenario-based financial planning: the case of Ukrainian railways. National Accounting Review, no 2(3), pp. 217-248. doi: 10.3934/NAR.2020013.

EVALUATING THE EFFECTIVENESS OF INNOVATION IMPLEMENTATION AT TRANSPORT ENTERPRISES UNDER CONDITIONS OF UNCERTAINTY

Oksana O. Karpenko, Academician Y. Bugay International Scientific and Technical University, Kyiv (Ukraine).

E-mail: o.karpenko@istu.edu.ua

Olha O. Kravchenko, State University of Infrastructure and Technologies, Kyiv (Ukraine).

E-mail: kravch.olha@gmail.com

Olena M. Palyvoda, National Aviation University, Kyiv (Ukraine).

E-mail: Palyvoda_olena@ukr.net

Svitlana M. Semenova, State University of Trade and Economics, Kyiv (Ukraine).

E-mail: s.semenova@knute.edu.ua

https://doi.org/10.32342/3041-2137-2025-2-63-5

Keywords: innovation evaluation, innovation efficiency, uncertainty, transport, scenario modeling, homomorphism

JEL classification: C53, L92, R42

In the conditions of economic uncertainty associated with war, the task of developing and applying new approaches to assessing the economic efficiency and feasibility of introducing innovations at transport enterprises has become more urgent. In the presented study, a mental model for the formation of the effects of innovations was developed based on scenarios that describe existing relationships and trends, with the aim of incorporating them into the planning of innovative activities at a transport enterprise using PJSC Ukrzaliznytsia as an example. The authors have demonstrated that, under current conditions, scenario modeling is advisable for forecasting innovative development. Based on the expert survey, a system of scenarios for the implementation of the innovative project was developed: «Innovative growth», «Insufficient demand», «Insufficient supply», «Resource conservation». The study evaluated the potential effectiveness of introducing innovations to improve transport (railway) infrastructure under the «Insufficient demand» and «Insufficient supply» scenarios for PJSC Ukrzaliznytsia. It was calculated that, under the «Insufficient demand» scenario, the efficiency of innovation would be negative but with a tendency towards further growth from -9.4% in 2025 to -11.8% in 2029. Under the «Insufficient supply» scenario, a negative result from the introduction of innovations was also obtained, but with a tendency to decrease from -0.4% in 2025 to -0.1% in 2029, which would lead to an increase in the level of transport demand from 76.81% in 2025 to 89.23% in 2029. It was determined that, under current conditions, the scenario «Insufficient supply» would be more effective as its implementation would ensure an increase in the level of satisfaction of transportation needs through increased funding for the innovative project. The analysis of scenarios showed that it is possible to reduce the probability of unwanted effects by implementing an effective planning system and using modern financing mechanisms for innovative activities of transport enterprises.

Одержано 19.09.2024.