This paper reports a study of the main key components of influence on the stability of transportation enterprises in the market. A model for evaluating the effectiveness of innovation activity in the transport industry, which takes into account indicators of expenditures on innovations, has been built. It makes it possible to determine the effectiveness of introduced innovations, which indicates the appropriate level of innovation potential and the ways that the enterprise must take to increase it. The main directions of innovative development of transportation enterprises were investigated.

The assessment of the economic stability of transportation enterprises in the market has established that the current state of development of enterprises is characterized by a weak level of their innovative activity.

A systematic approach to the introduction of innovative technologies by a transportation enterprise in the market has been devised. This approach makes it possible to determine the required level of enterprise stability and to form a relationship between the level of innovative technologies and their stages of implementation under conditions of environmental variability. This makes it possible to increase competitive advantages, improve the efficiency of production and economic activity of enterprises.

The practical implementation of the proposed model for evaluating the effectiveness of innovation activity in the transport industry has been carried out, which made it possible to allocate the most important indicators of innovation activity for the enterprise. These include specific efficiency of innovation; unit costs of innovation; innovative potential of the enterprise (defined as the proportion of own innovative developments). According to the study results, it is determined that the specific efficiency of innovations (SEI) exerts the greatest influence, which, with an increase by 1 %, provides an increase in financial stability by 1.48 %

Keywords: innovative technologies, system approach, stability of transportation enterprises, innovative activity

DEVISING A SYSTEMATIC APPROACH TO THE IMPLEMENTATION OF INNOVATIVE TECHNOLOGIES TO PROVIDE THE STABILITY OF TRANSPORTATION ENTERPRISES

Serhii Smerichevskyi
Doctor of Economic Sciences, Professor, Dean
Faculty of Economics and Business Administration*
Oleksii Mykhalchenko
PhD, Associate Professor, First Vice-Rector*
Zarina Poberezhna
Corresponding author
PhD, Associate Professor
Department of Economics and Business Technology*
E-mail: zarina_www@ukr.net
Igor Kryvovyazyuk
PhD, Professor
Department of Entrepreneurship, Trade and Logistics
Lutsk National Technical University
Lvivska str., 75, Lutsk, Ukraine, 43018
*National Aviation University
Liubomyra Huzara ave., 1, Kyiv, Ukraine, 03058

1. Introduction

The development of world transport infrastructure is one of the priority directions for ensuring sustainable development of both the global economic system and the economy as a whole. As one of the key infrastructure sectors, transport provides the necessary conditions for the life of the international community, the implementation of socio-economic and geopolitical tasks of the country on the way to integration into the world economic system.

Transport is an intersectoral system that determines the conditions for the reproduction of a particular country in accordance with the level of its development, and also guarantees the unity of the economic space and the dynamic development of the country's economy, the competitiveness of its subjects in the world market.

Modern transformation processes taking place in the transport infrastructure create conditions for modernization and integration, ensure the country's leadership on the global economic platform. This is manifested through the possibility of using the transit potential of the country, the unique economic and geographical position under the influence of integration processes, through systematic and integrated approaches aimed at the growth of the national economy.

On the way to increasing the competitiveness of the economy, the strengthening of innovation activity becomes of paramount importance. This is due to the fact that gradual structural changes and significant renewal of real sectors of the economy are key to ensuring sustainable economic development. Modern economic conditions determine the objective need to increase the level of flexibility and adaptability of the functioning of transportation enterprises and ensure their appropriate level of stability. The use of innovative technologies and processes, the development and implementation of innovative types of products makes it possible to take a leading position in the market, provide products with a high

degree of knowledge intensity and novelty, thereby making it competitive in the world market. That is why the definition of modern problems and the substantiation of practical recommendations for the direction of transportation enterprises to innovative development are of particular relevance. The use of innovative technologies in all processes of its activity is also becoming relevant, which will ensure the stability of functioning in the market in today's changing environment.

2. Literature review and problem statement

Paper [1] determined that the stability of the enterprise characterizes its state, which ensures stable functioning and progressive development of the enterprise under the negative influence of the external environment. However, there is no focus on a systematic approach to solving this issue. It is also advisable to consider the features of the functioning of individual components of the innovative potential of the enterprise in accordance with the conditions of its functioning.

Study [2] proposed to define the enterprise stability as an activity aimed at stimulating the innovative activity of the enterprise. It is noted that enterprises can receive additional benefits from the provision of new types of services, the creation of innovations and their development in production in order to obtain a new or improved production technology. However, there are unresolved issues related to achieving the effective functioning of the enterprise and ensuring its effectiveness, which becomes possible only on the basis of proactive and coordinated actions of management in accordance with the development strategy. As part of this, it is advisable to ensure the flexibility of the enterprise depending on changes in the external environment, as well as the formation of rational processes based on the innovativeness of their development.

Paper [3] formed the enterprise stability as a way of doing business, existing in close connection with innovation and commercializing new ideas and technologies of the enterprise on an innovative basis, as well as generating new knowledge. The company is in constant modernization and restructuring of the management system, capital investments in the creation of new technologies. However, there is no determination of the volume of investments in the development and implementation of innovations, as well as determining the effectiveness of the results obtained. That is why enterprises are of particular importance for the implementation of continuous monitoring of the dynamics of performance indicators of the enterprise under the influence of changes in the parameters of innovative development.

The authors of work [4] identified strategic directions of development of the transport sector and proposed to use new innovative technologies for traffic management both in domestic and international markets. The emphasis is formed on the development of value propositions and the use of opportunities for the stability of enterprises in the long term on the basis of innovative development. However, the work does not define the mechanism and limiting capacity of enterprises to finance innovations.

Under modern business conditions, it is innovative technologies that make it possible to form an innovative enterprise. Paper [5] determined that the market of transport services is formed under the influence of the latest achievements of technological progress through further computerization and digitalization, automation of all processes by modernizing existing basic technologies. However, it is not highlighted how several technological processes can be combined together, and how, on their basis, the formation of stability of enterprises takes place.

The study of the features of the transport services market as an environment for the functioning of transportation enterprises requires an understanding of the essence of the object, market entities, functions, as well as the conditions of existence and development that determine the specifics of the management of transportation enterprises. It should be noted that the level of functioning of enterprises is significantly influenced by the orientation to consumer requirements and the formation of supply in accordance with demand. That is why, paper [6] defined the conditions of formation, functions, and principles of development of the market of transport services. However, the work does not take into account methodological approaches to determining and forecasting the results of the enterprise, depending on the proposed components.

In work [7], it is noted that a modern transportation enterprise is a complex system, the effective functioning of which requires a comprehensive optimization of all processes and characteristics. Which is achieved only through the introduction of both technological and organizational and marketing innovations in all spheres of its activity. Based on the above, it can be argued that it is expedient to direct the activities of the enterprise to an innovative path of development and the creation of flexible organizational structures. This encourages business leaders to increasingly apply the principles of reorganization of financial and economic relations to increase the level of competitiveness of the enterprise on the basis of innovation.

One of the ways to solve the problems of innovative development in the transport industry should be an effective state innovation and investment policy, which is aimed at developing new methods of introducing innovative technologies. The need to analyze modern trends in innovative development and features of their application at transportation enterprises. That is why, work [8] identified the possibilities and necessity of innovation in transportation enterprises, but the work does not take into account the assessment of the effectiveness of transportation enterprises from the introduction of innovations.

The use of innovations plays an important role for the development of the transport industry as a whole, and for transportation enterprises, which will improve the quality of services, increase productivity and quantity of transportation. And as a result, increasing market share, entering new markets and reducing production costs. In [9], a theoretical and methodological approach to the formation of the national innovative transport hub as a system of state regulation of innovative development of transport infrastructure is proposed. Its implementation will ensure that the level of their provision and infrastructure development is brought closer to European standards. On the basis of the above, it can be argued that ensuring socially responsible innovative development of transport infrastructure is becoming important.

In [10], it is indicated that for the successful management of a transportation enterprise it is necessary to use innovative technologies to automate its activities. The author of the work admits that automation tools improve the distribution and management of inventory, make it possible to automate supply chain management processes as much as possible, which contributes to improving the quality of customer service, warehouse management, interaction with suppliers. However, it is not highlighted what approaches will allow the company to successfully implement, use, and further develop innovative technologies, which ensures the formation of stability of enterprises.

However, measures and ways to form the stability of transportation enterprises in the introduction of innovative technologies, through the development of a systematic approach, were ignored. This will allow forming sustainable long-term competitive advantages and increasing the level of competitiveness of the transportation enterprise. This indicates the feasibility of conducting research into the use of innovative technologies based on taking into account financial opportunities to ensure an appropriate level of stability of transportation enterprises in order to achieve the desired goal.

3. The aim and objectives of the study

The aim of this study is to develop an approach to the formation of stability of transportation enterprises through the introduction of innovative technologies. This will provide an opportunity to stimulate their innovation activity and constant modernization of the technological state on the basis of innovation.

To accomplish the aim, the following tasks have been set:
– to develop the concept of an approach to the formation of stability of transportation enterprises
– to form the main directions of innovative development of transportation enterprises in the market;
– to apply a mathematical model for evaluating the effectiveness of innovation activity in the transport industry;
– to assess the level of economic stability of transportation enterprises in the market and determine the level of their innovation.

4. The study materials and methods

The object of research is the process of forming the stability of transportation enterprises based on the introduction of innovative technologies. The hypothesis of the study was that the formation of stability of transportation enterprises directly necessitates the use of innovative development, in particular innovative technologies, which will increase the profitability of the enterprise, effective functioning in the market and will make it possible to obtain sustainable competitive advantages in the strategic period. The assumptions made in the study necessitated the use of certain methods that can be divided depending on the directions of our research: theoretical; analytical; research; pragmatic. The theoretical group of methods used in the study includes formalization, grouping and graphic – in the development and justification of the introduction of innovative technologies by transportation enterprises. Financial, economic, regression and statistical analysis – to define and generalize trends in the level of innovative potential of transportation enterprises. A set of general scientific and special methods of cognition is used, namely: system analysis and synthesis, theoretical generalization and comparison. These methods were used to determine the level of stability of transportation enterprises, which is achieved in assessing the sources of available resources of the enterprise and the level of its innovative development.

Based on the substantiation of theoretical-methodological, conceptual, and applied provisions, an analysis was carried out on the possibility of their application in practice for transportation enterprises. To verify the results of the formation of stability of transportation enterprises based on the introduction of innovative technologies, the data from the State Statistics Service of Ukraine were used.

5. Results of the study on the formation of stability of transportation enterprises in the market using innovative technologies

5. 1. Development of the concept of an approach to the formation of stability of transportation enterprises

In today's changing environment, enterprises must follow an innovative path of development. This is due to the fact that it is the principles of innovation management, based on the effective use and implementation of innovative technologies, that make it possible to adapt to changes in the transport services market. Achieving the desired synergistic interaction between the company's strategy and financial goals is one of the ways to ensure its stability as a whole.

The development of a strategy and innovative development programs in line with EU standards is a tool to achieve these goals, which should support fair and efficient transportation prices. It is also effective to introduce multimodality, digitalization, digital innovative technologies in the field of transport and logistics. Digital innovative technologies contribute to the creation of a multimodal transport system and form an innovative potential that creates new jobs, increases GDP and economic well-being of the population. The development and integration of the transport network eliminates existing barriers in the market and facilitates the interaction between various electronic systems and technological standards in order to optimize processes and services for providing services to consumers. One of these is digitalization, which creates a competitive advantage, finding new and retaining existing customers in the industry.

The main prerequisite necessitating the use of innovative technologies by transportation enterprises in the market include:
– intensification of competition and attempts to maximize profits;
– increase in consumer demand for services; the need to form a positive image and reputation of the enterprise;
– introduction into the process of providing services of scientific inventions and developments to improve the efficiency of the enterprise.

Long-term competitive advantages arise only when an enterprise continuously improves its innovative technologies with their widespread use.

Given the complexity and importance of applying innovative technologies for transportation enterprises, there is an objective need to form a management system that would cover all stages of the innovation process. She also contributed to the efficient use of resources, controlled all stages, implemented measures and solved the main tasks to ensure the enterprise stability.

To this end, achieving a high level of stability of transportation enterprises in the market is possible through the use of innovative technologies, which reduces the level of financial risk and guarantees solvency, increases the efficiency of using equity. Consequently, the formation of a certain level of economic stability can be the key to a stable increase in the profitability of doing business, ensuring creditworthiness, competitiveness and investment attractiveness of the enterprise in the market.

The introduction of innovative technologies by transportation enterprises makes it possible to increase competitive advantages, improve the efficiency of production and economic activity in general, since the transport industry is one of the priority sectors of the economy. The prerequisites for the formation of stability of transportation enterprises, which are directly influenced by both macroeconomic factors and the consumer sector, have been determined. An important factor in the formation of stability of transportation enterprises is the increase innovative potential through the establishment of assessment principles: financial condition, factors of influence and components of innovative potential, formation of a value chain of innovative technologies, strategies and forms of technology transfer. With this in mind, Fig. 1 shows a structural and logical scheme of transportation enterprises with the use of innovative technologies.

The enterprises engaged in the introduction of innovative technologies should be aware of the need for a systematic approach to the evaluation of innovative projects and programs and their management, depending on their nature, these tasks should be considered at the appropriate levels of management. With this in mind, Fig. 2 shows a block diagram of a systematic approach to the introduction of innovative technologies of transportation enterprises in the market.

The systematic approach considers the economic stability of transportation enterprises as a set of interrelated components that ensure their sustainable development. This is manifested through the establishment of interdependent relationships between the level of innovative technologies and their stages of implementation, as well as the formation of stable structural links between them under conditions of environmental variability.

Prospects for further developments on the formation of stability of transportation enterprises are the phased introduction of innovative technologies, optimization of parameters and terms of development of new products to ensure its competitiveness.

For transportation enterprises, it is possible to distinguish the stages of introduction of innovative technologies depending on their complexity and science intensity, adaptation of new technologies to the existing capabilities of the enterprise, which will ensure competitive advantages:

– development of innovative technologies capable of ensuring sustainable development of the enterprise;

– installation of innovative technologies of leading enterprises of the industry to the conditions of this enterprise, which adopted this technology, as well as adaptation of products to the market in which the company intends to compete;

– technological leap is aimed at both the production of new products and the search for new technologies [11, 12].
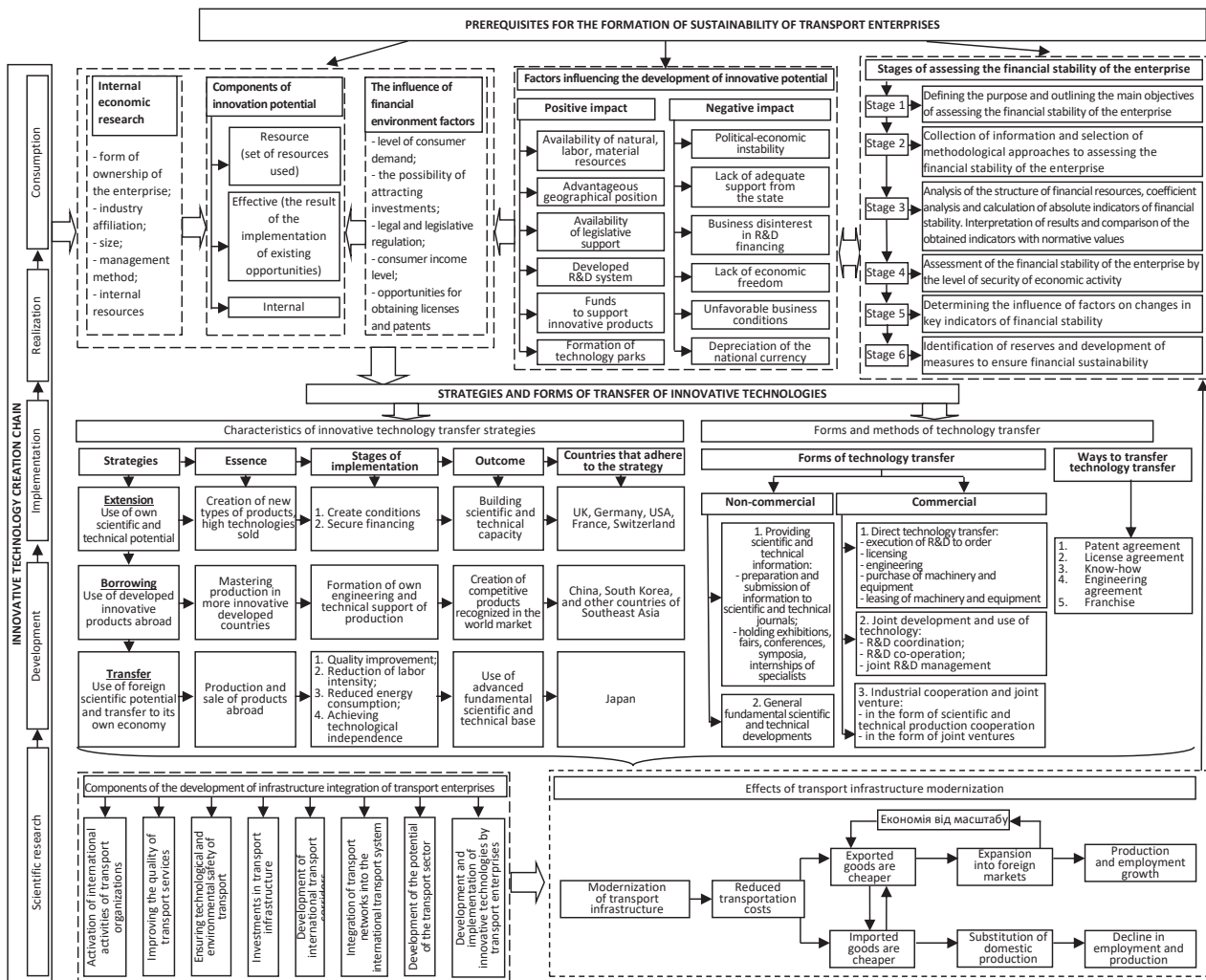

Fig. 1. Structural and logical scheme of formation of stability of transportation enterprises with the use of innovative technologies
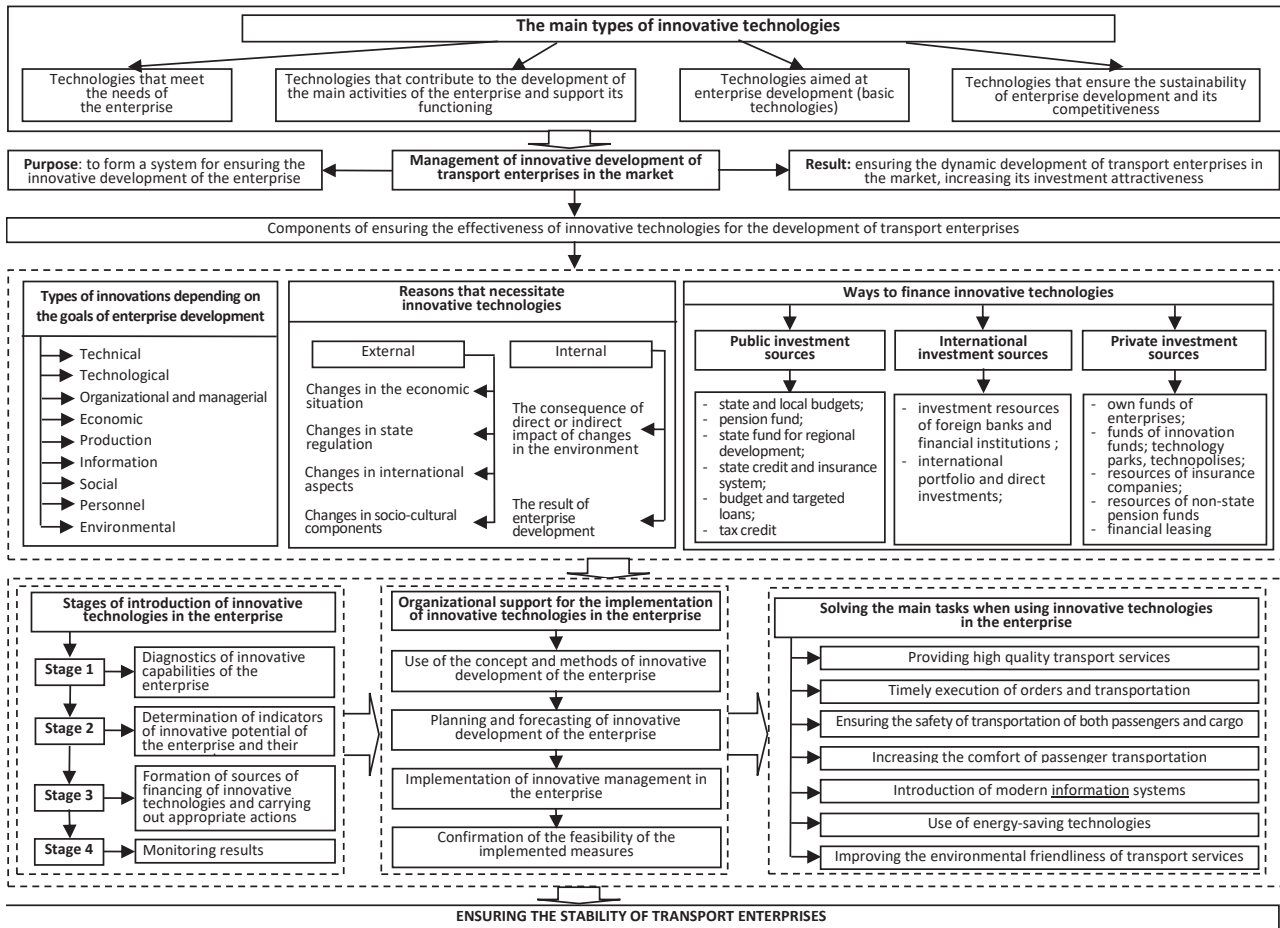
Fig. 2. Block diagram of a systematic approach to the introduction of innovative technologies of transportation enterprises in the market

The use of innovative technologies in the management of a transportation enterprise is an important competitive tool to ensure its economic stability in the market. It can be argued that the innovation-oriented enterprise in its activities is characterized by the following areas:

– conducts research and development (or purchases new innovative projects in a relatively wide range);

– transfers significant financial resources to innovation activity;

– constantly introduces new scientific and technical solutions;

– has a significant share of innovative products and technologies, and constantly implements them in its activities [13].

The introduction of the proposed approaches to enterprise management, taking into account the requirements of the services market, industry and regional characteristics, is a priority task for achieving the efficiency and competitiveness of the transport industry in the region.

5. 2. Directions of innovative development of transportation enterprises in the market

Innovative development of transport is to create conditions for economic growth, increase the competitiveness of the national economy and the quality of life of the population. This is achieved through providing access to safe and modern transport services, transforming the geographical features of the country into its competitive advantages [14, 15].

The rapid development of the service sector is a condition for the successful development of the national economy. Some sectors of the service sector, including the transport industry, have acquired key importance for the functioning of the economy and socio-economic development of the country. Among those, Ukraine has a fairly advantageous geographical location on the Eurasian continent, which made it possible to form a strong transport hub in the country, through which important trade and transport routes pass. But at the present stage, the transport system of Ukraine has many problems, the main of which is the inconsistency of the technological and technical level of domestic transport with European requirements. Also, the lag in the development of transport services, low level of service, unsatisfactory level of transportation safety, significant environmental burden of transport on the environment. All this affects the decline in the competitiveness of transport in world transportation markets. The solution of these problems is possible through the introduction of innovative technologies by transportation enterprises, which will positively affect the development of the transport system of Ukraine and ensure the enterprise stability [16].

Thus, analyzing the statistics of passenger transportation in Ukraine for 2017–2021, we note that road transport is the most common type among passengers. Since it has a fairly extensive infrastructure and the greatest mobility among all types of local passenger transport (Fig. 3).
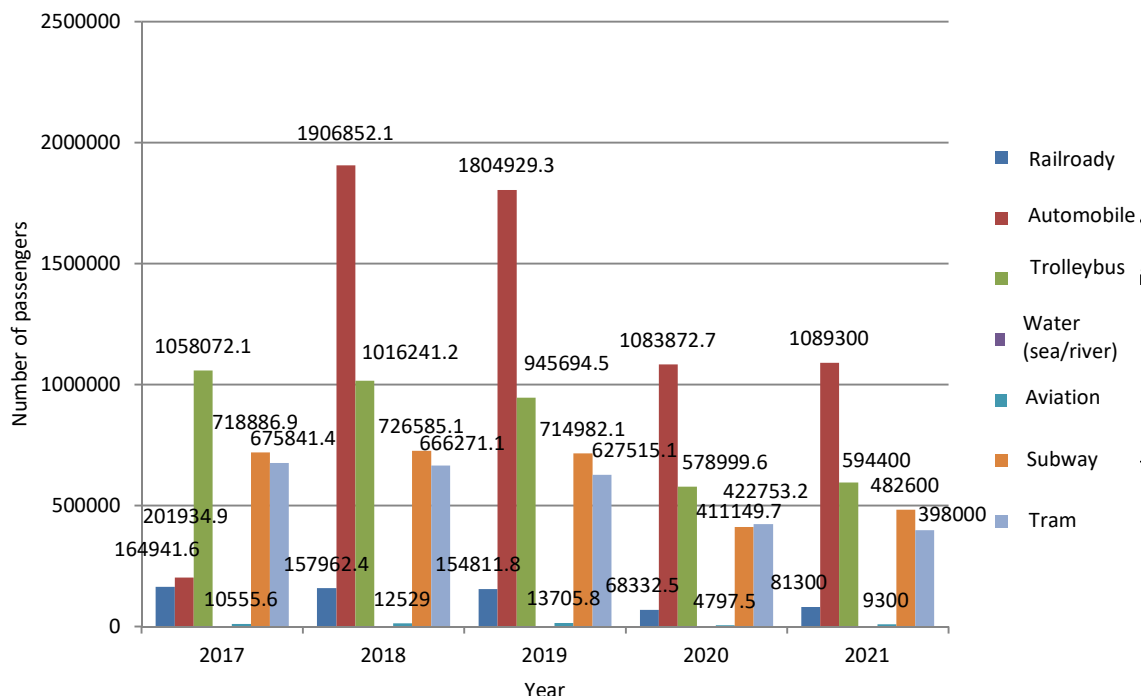
Fig. 3. Dynamics of the number of passengers transported in 2017—2021

As evidenced by the dynamics of the number of passengers transported during 2017–2021 by all modes of transport (Fig. 3), the largest reduction in passenger traffic occurred in rail, air, and road transport. In particular, the fall in passenger traffic is influenced by a number of negative factors, including the global pandemic Covid-19 and border closures, restrictions on travel in the regions of Ukraine and in cities.

Existing and new challenges and threats require continuous improvement of institutional mechanisms for regulating the passenger air transportation market, including competitive environment, staffing, financial performance, consumer protection, national security, and individual passenger security [17].

In the structure of passenger turnover, the largest share of passengers transported falls on road transport, the share of which was 42 % in 2021 (Fig. 4). At the same time, there is a tendency to fall in the level of passenger turnover in railroad transport and a simultaneous increase in the share of passengers transported by air [18].

We believe that the modernization of road transport should be associated with the integrated development of roads, trunk networks, taking into account the directions of territorial development of the regions. Also, increasing the density and capacity of backbone networks, improving the comfort and safety of transport services [19].

Thus, while rail transport accounted for 27.5 % of passenger traffic in 2018, in 2019 this position was taken by air transport, whose share in the structure of passenger turnover was 28.2 %, and rail transport – only 26.5 %. This trend indicates a redistribution of the passenger transportation market, which is largely due to the discrepancy between the quality of railroad transport services and modern passenger requirements [20]. For railroad transport, significant problems arise due to moral and physical deterioration of rolling stock and vehicles, high capital intensity, material consumption and energy intensity of services.

That is, in general, we can state negative trends in the activities of transportation enterprises, associated, among other things, with the influence of world factors, as well as a low level of technological potential and innovative development in enterprises. In order to increase the competitiveness of transport services, it is necessary to organize and implement a nationwide innovation program aimed at increasing the investment potential of the enterprise. Introduction of innovative technologies developed on a scientific basis with the use of new knowledge, subject to compliance with the advanced world technical market of high-tech products.

Innovative activity at the transportation enterprise should be aimed at solving the following tasks:

– ensuring high quality of transport services; timely execution of orders and transportation;

– ensuring the safety of transportation of both passengers and cargo;

– improving the comfort of passenger transportation; introduction of modern information systems; use of energy-saving technologies, increasing the environmental friendliness of transport services [21].

So, the directions of intensification of innovative development of the transport industry are:

– continuation of the introduction of innovative technologies and developments by business entities in transport;

– involvement of IT industry companies in cooperation to develop new business models for transportation enterprises, optimization of implementation processes of compatible innovative projects in transport, programs for the creation and provision of electronic transport services and electronic logistics services;

– development of leasing relations directly between vehicle manufacturers and transportation enterprises without involving unnecessary intermediaries in the process of purchase and sale;

– stimulating the development of innovative activity of transportation enterprises.
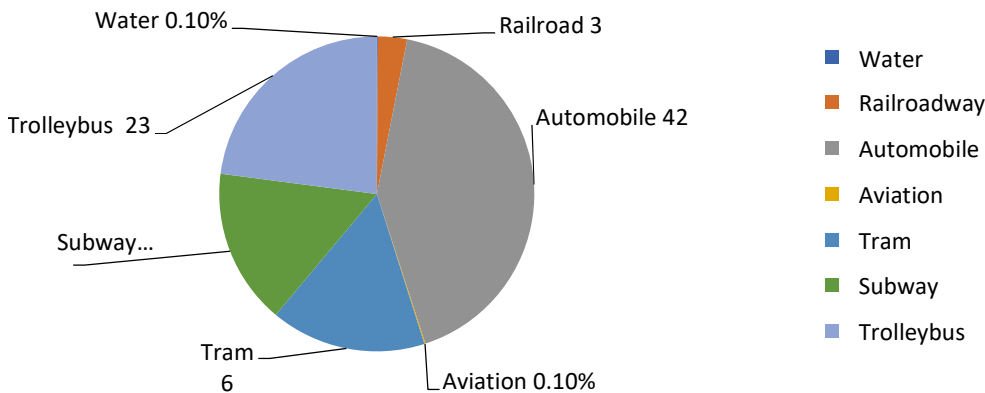
Fig. 4. Share of passengers transported in 2021

5. 3. Mathematical model for evaluating the effectiveness of innovation activity in the transport industry

An important factor in the development of innovation in the transport industry is the level of financing. And this very factor is the main obstacle to their innovative development. Innovation activity is stopped every year by hundreds of transportation enterprises. The main inhibitory factors for the implementation of innovation activity were a lack of both own and attracted financial resources, insufficient support of the state and imperfection of the legislative framework. Also, the lack of fundamental and lack of applied research in the industry, low demand for innovation, significant riskiness and long payback periods of innovations [7].

To assess the effectiveness of innovations in the transport industry, data on the costs of invested innovations were used (Table 1).

The main source of financing for innovation activity of transportation enterprises in the market is own funds of enterprises and state grants. It is clear that such a volume of financial resources is not enough for full-fledged innovative development. Table 2 gives the amount of own funds that enterprises invest in innovations and research.

Table 1

Expenditure on innovation, UAH million

Modes of transport	2017	2018	2019	2020	2021
Transport (in general), warehousing, postal and courier activities	3,125.0	3,305.0	1,780	2,364.2	1,876.1
Land and pipeline transport	988.2	1,045.2	674.2	376.0	398.2
Air transport	1,009.0	1,159.0	1,234.1	1981	1,023.4

Note: the buy/sell rate of USD at the time of calculation was in 2017 – UAH 26.6/26.8 UAH; in 2018 – UAH 27.2/28.05; in 2019 – UAH 23.7/24.6; in 2020 – UAH 27.8/28.1; in 2021 – UAH 27.12/27.5

Table 2

R&D at own expense, UAH million

Modes of transport	2017	2018	2019	2020	2021
Transport (in general), warehousing, postal and courier activities	1,198.5	1,252.7	1,251.2	1,257.3	1,109.2
Land and pipeline transport	8.2	7.1	8.9	9.2	10.1
Air transport	90.3	98.2	109.7	112.3	78.3

After analyzing the trends of innovation activity of transportation enterprises in Ukraine (Table 3), it can be argued that in recent years the number of innovatively active enterprises has decreased threefold. This indicates the presence of significant problems and a low level of innovation development, which negatively affects the competitiveness of products and the development of the economy as a whole [22].

Table 3

Number of innovatively active enterprises

Modes of transport	2017	2018	2019	2020	2021
Transport (in general), warehousing, postal and courier activities	557	568	345	133	145
Land and pipeline transport	309	294	124	66	72
Air transport	10	10	6	3	3

Quite an important characteristic of the effectiveness of innovation is the indicators of the volume of sold innovative products. Thus, the change in the volume of sold innovative products by a third is determined by the costs of domestic research and the cost of purchasing machinery, equipment and software, which are given in Table 4.

Table 4

Volume of sold innovative products (goods, services), UAH million

Modes of transport	2017	2018	2019	2020	2021
Transport (in general), warehousing, postal and courier activities	1,298.2	1,314.1	1,543.1	1,602.3	987.2
Land and pipeline transport	123.4	114.5	234.5	512.2	304.3
Air transport	987.3	980.7	998.5	1,002.4	834.8

The indices of expenditures on innovations for the period 2017–2020 were calculated, as well as the dependence of the share of innovatively active enterprises and volumes of sold innovative products on costs (Fig. 5).

On the basis of correlation analysis, a correlation matrix is obtained, where x_1 – expenditure on innovation, x_2 – number of innovation active enterprises, x_3 – volume of sold innovative products (goods, services), Table 5.

After checking the significance of the correlation coefficients with a significance level of at least 0.95, we can conclude that there is a significant direct relationship be-

tween the cost of innovation and the volume of innovative products sold. At the same time, the number of innovatively active enterprises in the industry is decreasing, which leads to an increase in the share of sales volumes of innovative products (Fig. 6).

vative potential of the enterprise (defined as the specific number of in-house innovative developments, UAH million). Table 6 gives the results of the specific value of sales volumes of innovative products.

This model is adequate with a reliability level of at least 0.985 (determined using the F-Fisher relation), while the coefficient of determination of the model is 0.99976, which also indicates its high reliability and the ability to use it for forecasting.

Table 5

Correlation matrix of innovative products sold (goods, services)

Indicator	x_1	x_2	x_3
x_1	1	−0.87826	0.736177
x_2	−0.87826	1	0.736177
x_3	0.736177	0.736177	1

According to the study, it is the aviation industry that is the most efficient and attractive for investment, but there is a problem that there are quite a few investment-active enterprises.

To model the relationship between the main indicators of innovation (Table 6), methods of regression analysis were applied, and the following model was built:

$$SEI = -9.9797 + 2.7937 \cdot PVI + 7.8819 \cdot IP, \quad (1)$$

where SEI – specific efficiency of innovations (ratio of innovation costs to research volumes performed in-house, UAH million); PVI – unit costs of innovation (UAH million); IP – inno-

Table 6

Indicators of innovation activity for the aviation industry, UAH million

| Modes of transport	Year	2017	2018	2019	2020	2021
Specific efficiency of innovations	Transport (in general), warehousing, postal and courier activities	2.76	2.64	1.42	1.88	1.79
	Land and pipeline transport	127.46	147.21	75.75	40.68	42.03
	Air transport	12.83	11.80	11.25	17.64	16.04
Innovative potential of the enterprise	Transport (in general), warehousing, postal and courier activities	2.15	2.21	3.63	9.45	7.45
	Land and pipeline transport	0.03	0.02	0.07	0.14	0.10
	Air transport	9.03	9.82	18.28	37.43	38.01
Unit costs of innovation	Transport (in general), warehousing, postal and courier activities	2.33	2.31	4.47	12.05	12.23
	Land and pipeline transport	0.40	0.39	1.89	7.76	6.59
	Air transport	98.73	98.07	166.42	334.13	245.98
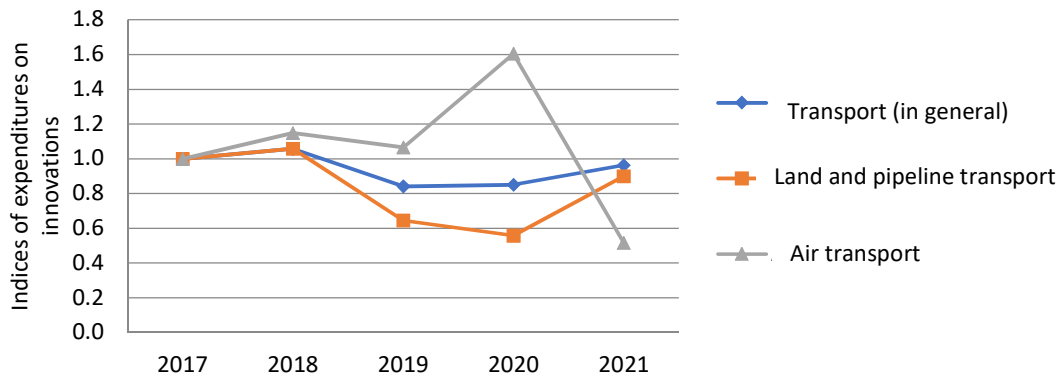
Fig. 5. Change in innovation cost indices
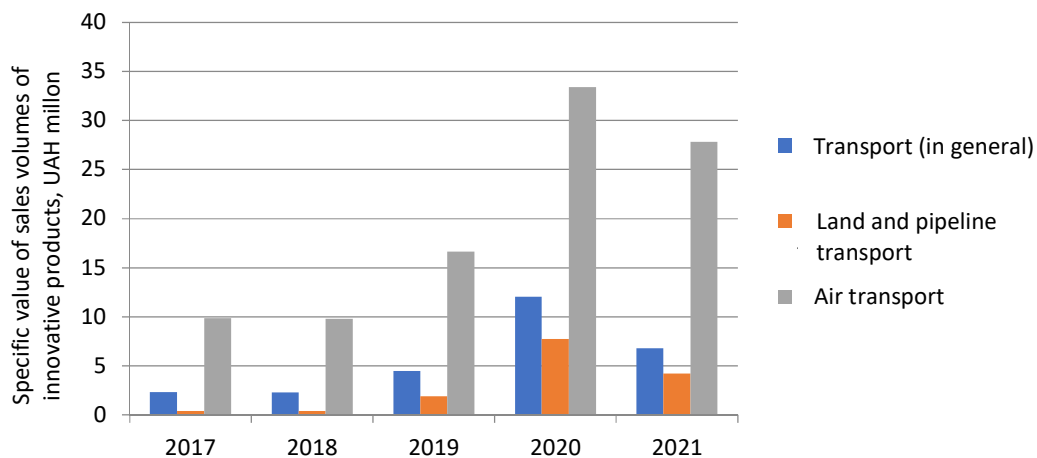
Fig. 6. The specific value of sales volumes of innovative products, UAH million

So, on the basis of the study, three main indicators were formed that characterize the level of innovation, namely: SEI – specific efficiency of innovations; PVI – unit costs of innovation; IP – innovative potential of the enterprise. These indicators are interrelated and make it possible to determine both the innovative potential, knowing the levels of the specific weight of the effectiveness of innovations and unit costs, and vice versa. Also, these indicators serve to assess the integral indicator of the effectiveness of innovation activity and to determine the stability of transportation enterprises in the market. However, it should be noted that in the current realities of Russia's military aggression against Ukraine, it is impossible to predict the number and real volume of innovations in the transport industry. Therefore, this model can be used as a key tool for the implementation of innovation policy in the postwar period and the period of industry development.

5. 4. Assessment of the level of economic stability of transportation enterprises in the market and determining the level of their innovation

Under modern economic conditions, ensuring the economic stability of transportation enterprises is one of the priority tasks, which makes it possible to function effectively in a changing external competitive environment. Assessment of the economic stability of transportation enterprises is a set of actions and tasks to determine the main indicators characterizing its condition. In accordance with the level of functioning, there are planned, planned or desirable, depending on the influence of external and internal factors. It can be argued that if an enterprise has a high level of financial stability, then it has more advantages over other enterprises. After all, it has more opportunities to attract investment, obtain loans and ensure a high level of qualification of personnel, and therefore has less risk of becoming bankrupt.

To assess the level of economic stability of transportation enterprises, we propose to tread the following stages:

Stage 1. Formation of a list of indicators of production stability:

$$(k_1, k_2, ..., k_n),$$

where k_1 – capital security;
  k_2 – labor productivity;
  k_3 – coefficient of renewal of PF (fixed assets);
  k_4 – coefficient of validity of PF.

Stage 2. Formation of the list of indicators of financial stability:

$$(f_1, f_2, ..., f_m),$$

where f_1 – measure of risk (coefficient of variation of net income);
  f_2 – net working capital;
  f_3 – coefficient of autonomy;
  f_4 – current liquidity ratio;
  f_5 – return on equity ratio;
  F_6 – profitability of products sold.

It should be noted that the set of indicators can be supplemented or changed by each enterprise or group of enterprises, depending on the purpose and methodology of analysis, available statistical data, etc.

Stage 3. Normalization of indicators. This procedure is a prerequisite for calculating integral indicators since it reduces

indicators to dimensionless values from the range [0, 1], and also makes it possible to compare multidirectional indicators, without which the formation of an integral index is impossible.

Normalization is carried out by comparing sample statistical values with certain reference values (maximum, minimum, or average).

Stage 4. Determination of weighting coefficients for each indicator: $(\mu_1, \mu_2, ..., \mu_n)$ – a set of weights for indicators of production stability, $(\lambda_1, \lambda_2, ..., \lambda_m)$ – a set of weights for indicators of financial stability.

Weighting coefficients can be determined by the method of expert assessment, based on statistical data or methods of factor analysis.

Stage 5. Calculation of integral stability indicators:
– integral indicator of production stability:

$$k = \sum_{i=1}^{n} \mu_i k_i;$$

– integral indicator of financial stability:

$$f = \sum_{i=1}^{m} \lambda_i f_i.$$

Stage 6. Calculation of values of key indicators of innovation:

x_1 – share of sold innovative products in the total volume of sales;
  x_2 – unit costs of innovation;
  x_3 – specific efficiency of innovations;
  x_4 – innovative potential of the enterprise (specific number of in-house innovative developments).

To determine the value , subject to known values of other quantities, you can use formula (1).

Stage 7. Determination of threshold values, that is, the establishment of limit values, going beyond which leads to negative consequences in the activities of the enterprise, in particular, forms the threat of risks of various nature.

To determine the threshold values of stability indicators, it is advisable to use methods for establishing functional dependences (macro/microeconomic, analytical or statistical equations). Also, the methods of Akhiezer-Holtz, information theory, the "golden section", macroeconomic models that adequately reflect the development of the industry as a whole and the impact of various positive and negative factors on it.

In the study, the method of determining optimal solutions in a matrix game was applied [23, 24]. Accordingly, each component (production stability, financial stability, efficiency of innovation, and innovation potential) was represented in the form of a matrix, the columns of which contained normalized values of individual indicators, and rows – a period of time. This matrix is reduced to an optimization problem, the solutions to which are the frequencies of optimal mixed strategies, which can be considered as a set of weights necessary for the formation of an integral index.

In this case, the lower and upper optimal values were determined as such fluctuations in integral indicators that do not lead to the exit of the system from the state of homeostasis. According to the procedure used, these values could vary in the range not exceeding 20 % deviation from the optimal value.

In order to practically implement the proposed methodology, the threshold values of the studied stability indicators for the transport industry of Ukraine in general and air transport in particular were determined, Table 7.

Table 7

Integral thresholds for stability indicators

Indicator	Lower threshold	Lower optimal value	Upper optimal value	Upper threshold
Integral indicator of production stability	0.2840	0.3768	0.6232	1
Integral indicator of financial stability	0.3682	0.5161	0.6640	1
Specific efficiency of innovations	0.2145	0.3908	0.6699	1
Innovative potential of the enterprise	0.2298	0.4071	0.7424	1

The calculated threshold values allow for a comprehensive assessment of the stability of a transportation enterprise, taking into account its innovative development.

The model for evaluating a transportation enterprise using the proposed algorithm can be represented as a four-dimensional matrix. For convenience, we present it in the form of a combination of two matrices – a matrix of comprehensive assessment of production and financial stability (Table 8) and a matrix of innovative development (Table 9).

The stability of equilibrium is understood as the ability of the enterprise to maintain the existing state of production and financial development, provided that even minor external negative influences can significantly worsen the main indicators of production and financial stability. The stability of operation is understood as the ability of the enterprise to keep the main indicators of activity within acceptable limits in the process of dynamic development. The stability of homeostasis characterizes the ability of an enterprise to respond quickly to negative impacts, counteract risks, and restore balance. Stability of development means constantly maintaining optimal indicators of production and financial activity under conditions of constant external and internal changes.

To better reflect the relationship between the main indicators of enterprise stability and indicators of innovative development, a correlation analysis is carried out, the calculations of which are given in Table 10.

The matrix of correlations between the main indicators of stability and the indicator of innovation of development makes it possible to conclude that indicators of production and financial stability significantly depend on indicators of innovative development. Macroeconomic models built on the basis of analysis allow us to draw the following conclusions, Table 11.

To confirm the effectiveness of the proposed model, calculations were performed for 3 enterprises of the transport industry, Table 12.

These studies were fully confirmed when analyzing the enterprises of the transport industry, which indicates the sufficient importance of introducing innovations that are directly related to the enterprise stability in the market.

Table 8

Matrices of comprehensive assessment of production and financial stability

		Integral indicator of production stability			
	Indicators	$k \in [0; 0.2840)$	$k \in [0.2840; 0.3768)$	$k \in [0.3768; 0.6232)$	$k \in [0.6232; 1]$
Integral indicator of financial stability	$f \in [0; 0.3682)$	Critically unstable state	Unstable condition	Equilibrium stability	Stability of functioning
	$f \in [0.3682; 0.5161)$	Unstable condition	Equilibrium stability	Stability of functioning	Persistence of homeostasis
	$f \in [0.5161; 0.6640)$	Equilibrium stability	Stability of functioning	Persistence of homeostasis	Stability of development
	$f \in [0.6640; 1]$	Stability of functioning	Persistence of homeostasis	Stability of development	Stability of development

Table 9

Matrices of complex evaluation of innovative development

		Specific efficiency of innovations			
	Indicator	[0: 0.2145]	[0.2145; 0.3908]	[0.3908; 0.6699)	[0,6699; 1]
Innovative potential of the enterprise	[0; 0.2298)	Critically low	Low	Satisfactory	Average
	[0.2298; 0.4071)	Low	Satisfactory	Average	Sufficient
	[0.4071; 0.7424)	Satisfactory	Average	Sufficient	High
	[0.7424; 1]	Average	Sufficient	High	Very high

Table 10

Matrix of correlations between the main indicators of stability and the indicator of innovative development

Indexes	Production stability	Financial stability	Innovative development
Production stability	1	0.961043	0.873131
Financial stability	0.961043	1	0.873131
Innovative development	0.873131	0.885437	1

Table 11

Generalized data for assessing the impact of investments on the effective indicator of enterprise stability

Model	Definition	Conclusion
The dependence of production stability on the specific efficiency of investments	$k = 0.2840 + 1.0267 \cdot SEI$, the standard error of the model does not exceed 0.01 with a significance level of 0.1	With an increase in the specific efficiency of investments by 1 %, the integral indicator of production stability will increase by an average of 1.03 %
The dependence of financial stability on the specific efficiency of investments	$f = 0.3682 + 1.4785 \cdot SEI$, the standard error of the model does not exceed 0.03 with a significance level of 0.1	With an increase in the specific efficiency of investments by 1 %, the integral indicator of financial stability will increase by an average of 1.48 %

Table 12

Calculation of integral indicators of stability

Types of enter-prises	Production stability	Financial stability	Innovative potential	Investment efficiency	Conclusion
Enterprise 1	0.4309	0.4256	0.4478	0.3870	Stability of functioning at an average level of innovative development
Enterprise 2	0.5987	0.5599	0.6012	0.2965	Stability of homeostasis with an average level of innovative development
Enterprise 3	0.1583	0.1480	0.1399	0.1899	Critically unstable state at a critically low level of innovation development

6. Discussion of results of ensuring the stability of transportation enterprises with the application of innovative technologies

There are a large number of procedures for improving and shaping the enterprise stability, which are proposed by researchers of our time [1–10]. All of them are integral and contain a significant number of components for calculation, others – on the contrary, few. In contrast to the existing approaches, in this paper a systematic approach to the introduction of innovative technologies by transportation enterprises in the market is proposed (Fig. 2). This approach makes it possible to establish qualitative and quantitative characteristics that determine the degree of effectiveness of management and functioning.

To ensure the effective functioning of transportation enterprises, prerequisites for the formation of stability with the use of innovative technologies have been formed. The influence of factors and components of innovative potential, as well as the form and strategy of transfer of innovative technologies, which makes it possible to determine the effect of modernization of transport infrastructure and assessment of existing innovative potential (Fig. 1).

Our approach to ensuring the stability of transportation enterprises makes it possible to determine the volume of sales of innovative products using innovative technologies. During the study, using mathematical tools, an assessment of the level of innovative potential and the feasibility of the results obtained to determine the stability of transportation enterprises were carried out. On the basis of further decisions on the reorganization or introduction of new innovative technologies in the activities of the enterprise.

The study of economic stability of transportation enterprises allowed us to determine the most important for their functioning volumes of specific efficiency of innovations (SEI), the whole procedure for calculating the stages of approach is given in Tables 7–12, as well as the calculation.

As a result of the assessment of the stability of transportation enterprises, it is determined that the level of innovative development has the greatest influence, a detailed analysis is given in Table 12. It is possible to draw a number of important conclusions about the effectiveness of innovations in the activities of enterprises and their orientation to the relevant sources of investment resources.

Therefore, it can be argued that the current state of development of transportation enterprises in the market using the presented model makes it possible to draw a general conclusion about the weak level of their innovative activity. The application of the integrated assessment model based on the developed indicators makes it possible to form further ways to increase the innovative potential, as well as determine the problems of stability of transportation enterprises in the market and directions for their solution.

However, in the study on the introduction of innovative technologies for the formation of stability of enterprises, only transportation enterprises were used. This, accordingly, limits the field of research on practical use and outlines the scope of further research in the direction of applying the proposed methods and practical recommendations for enterprises in other industries.

The disadvantage of the study is that the effectiveness of the proposed recommendations is confirmed by the feasibility and practicality of their implementation in the activities of enterprises that have a certain level of funding for the application of innovations and innovative technologies in all production processes.

In the future, it is advisable to investigate the mutual influence of all components of the innovative potential of transportation enterprises to improve the activities of functional areas, develop appropriate strategies and implement innovation and investment opportunities to ensure sustainable competitive advantages.

7. Conclusions

1. A concept of approach to formation of stability of transportation enterprises through introduction of innovative technologies has been developed, which will determine the level of their innovative development, as well as ways to increase it. The main prerequisites and factors influencing the stability of transportation enterprises are determined, a systematic approach is proposed, which takes into account the principles, types and reasons for using innovative technologies, as well as ways to finance them. The developed concept gives advantages to the proposed approach as it provides an opportunity to rationally use time when describing the relationship between the results of the use of innovative technologies and the costs of achieving them.

2. The main directions of formation of stability of transportation enterprises are investigated, among which the main ones are highlighted: ensuring high quality of transport services, ensuring the safety of transportation of both passengers and cargo, constant modernization and automation of service provision processes. At the same time, the following aspects of activation of innovation activity of transportation enterprises such as conducting research and development of new innovative technologies and products,

allocating funding for the development of R & D, increasing the investment attractiveness of enterprises, attracting specialists from IT-industry, the use of modern business technologies.

3. A mathematical model for evaluating the effectiveness of innovation activity in the transport industry to ensure the stability of transportation enterprises has been proposed, which makes it possible to provide the necessary level of innovative flexibility of enterprise and independence in the application of innovative technologies. The model is a linear regression equation that relates the specific efficiency of innovations with two input variables: the unit cost of innovation and the innovative potential of the enterprise. It is found that with an increase in the unit costs of innovation by UAH 1 million, the specific efficiency of innovations will increase by an average of UAH 2.794 million, and with an increase in the share of own innovative developments by UAH 1 million, the specific efficiency will increase on average by UAH 7.882 million. We also substantiated the existence of a significant direct correlation between the costs of implemented innovative products and the cost of innovation in the transport industry and the number of innovation-active enterprises. At the same time, the relationship between the last two indicators turned out to be the opposite, which may indicate that in the period 2017–2021 the number of innovatively active enterprises decreased while the volume of innovative products sold grew.

4. The economic stability of transportation enterprises was assessed by determining indicators of production and financial stability, as well as innovative potential of enterprise. It was found that with an increase in the specific efficiency of investments by 1 %, the integral indicator of production stability will increase by an average of 1.03 %, and with an increase in the specific efficiency of investments by 1 %, the integral indicator of financial stability will increase by an average of 1.48 %. On the basis of the proposed methodology for calculating integral indicators, a model of comprehensive assessment of production and financial stability, as well as innovative development, has been built. Testing of the proposed model for transportation enterprises led to the conclusion that among the three studied enterprises, one is in a state of homeostasis at an average level of innovative development, the second is in a state of stability of functioning with an average level of innovative development, and the third is in a critically unstable state with a critically low level of innovative development.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

Funding

The study was conducted without financial support.

Data availability

All data are available in the main text of the manuscript.

References

1. Maliarets, L. M., Smoliakova, O. M. (2015). Optymizatsiya znachen pokaznykiv ekonomichnoi stiykosti pidpryiemstva. Visnyk Khmelnytskoho natsionalnoho universytetu. Ekonomichni nauky, 1 (220), 11–23.

2. Vorona, A. (2020). Innovative activity of enterprises as a prospect of development of the national economy of Ukraine. Efektyvna ekonomika, 3. doi: https://doi.org/10.32702/2307-2105-2020.3.155

3. Kreidych, I., Bielova, A., Olijnyk, G. (2019). Forming the conditions of innovative development of enterprises in the transformation economy. Baltic Journal of Economic Studies, 5 (4), 122. doi: https://doi.org/10.30525/2256-0742/2019-5-4-122-129

4. Rakhman, M. (2021). Marketing Analysis of Transport Services of Ukraine in the Foreign Market. Modern Economics, 29 (1), 143–150. doi: https://doi.org/10.31521/modecon.v29(2021)-22

5. Kushnir, N., Syusko, O. (2019). Analysis of the current state of the world market of transport services. Geopolitics of Ukraine: History and Modernity, 2 (23), 135–146. doi: https://doi.org/10.24144/2078-1431.2019.2(23).135-146

6. Braykovska, A. (2012). Research of transport services' market as operation environment for transport companies. Ekonomist, 9, 50–54. Available at: http://nbuv.gov.ua/UJRN/econ_2012_9_14

7. Komchatnykh, O. V. (2018). Financing innovative development of Ukrainian transport enterprises. Hlobalni ta natsionalni problemy ekonomiky, 22, 402–407. Available at: http://global-national.in.ua/archive/22-2018/78.pdf

8. Stovba, T., Zhuk, T., Tsercovna, A., Slatvinska, V. (2021). Innovative development of transport sphere: economic, marketing, educational aspects. LAPLAGE EM REVISTA, 7 (3), 423–434. doi: https://doi.org/10.24115/s2446-62202021731321p.423-434

9. Dmytriieva, O. I. (2020). National innovative transport HUB as a system of state regulation of innovative development of transport infrastructure. Management, 31 (1), 38–48. doi: https://doi.org/10.30857/2415-3206.2020.1.3

10. Jović, M., Tijan, E., Perić Hadžić, A., Karanikić, P. (2020). Economic aspects of automation innovations in electronic transportation management systems. Pomorstvo, 34 (2), 417–427. doi: https://doi.org/10.31217/p.34.2.22

11. Honcharenko, O. M. (2012). Vplyv innovatsiynykh tekhnolohiy na stiykist funktsionuvannia pidpryiemstva. Visnyk sotsialno-ekonomichnykh doslidzhen, 1, 167–174.

12. Ameen, N., Choudrie, J., Jones, P., Anand, A. (2022). Innovative Technologies and Small-Medium Sized Enterprises in Times of Crisis. Information Systems Frontiers, 24 (4), 1055–1060. doi: https://doi.org/10.1007/s10796-022-10353-7

13. Borowski, P. F. (2021). Innovation strategy on the example of companies using bamboo. Journal of Innovation and Entrepreneurship, 10 (1). doi: https://doi.org/10.1186/s13731-020-00144-2

14. Polischuk, O. M. (2015). Innovative transformation as a factor for transport modernization of traffic management in large cities. Formuvannia rynkovykh vidnosyn v Ukraini, 7, 45–49. Available at: http://nbuv.gov.ua/UJRN/frvu_2015_7_13

15. Seniv, L. (2022). Organizational issues with urban passenger transportation. Economy and Society, 44. doi: https://doi.org/10.32782/2524-0072/2022-44-96

16. Danylkiv, K. P., Horbova, K. V., Poburko, O. Y. (2018). Innovative Development of the Transport System of Ukraine. Scientific Bulletin of UNFU, 28 (4), 31–35. doi: http://dx.doi.org/10.15421/40280405

17. Smerichevskyi, S., Gura, S. (2021). System economic dynamics of passenger air transport and institutional mechanisms of its regulation. Problems of systemic approach in the economy, 2 (82), 46–53. doi: https://doi.org/10.32782/2520-2200/2021-2-6

18. Dmytriieva, O. (2021). Forming a scientific paradigm of state regulation for innovative development of transport infrastructure. Problemy i perspektyvy rozvytku pidpryiemnytstva, 1 (26), 34–44. doi: https://doi.org/10.30977/PPB.2226-8820.2021.26.34

19. Smerichevskyi, S., Raicheva, L., MykhalchenkoO. (2022). Problems and prospects of modernization of the transport complex of the national economy. Economy and Society, 38. doi: https://doi.org/10.32782/2524-0072/2022-38-76

20. Yannis, G., Chaziris, A. (2022). Transport System and Infrastructure. Transportation Research Procedia, 60, 6–11. doi: https://doi.org/10.1016/j.trpro.2021.12.002

21. Mashkantseva, S., Sclar, L. (2019). Nnovative development of the region transport system: problems and prospects. Ukrainskyi zhurnal prykladnoi ekonomiky, 4 (1), 48–54.

22. Pysarenko, T. V., Kvasha, T. K., Rozhkova, L. V., Kovalenko, O. V. (2020). Innovatsiina diialnist v Ukraini u 2019 rotsi. Kyiv: UkrINTEI, 45. Available at: https://mon.gov.ua/storage/app/media/innovatsii-transfer-tehnologiy/2020/08/za-2019-1-1.pdf

23. Derzhavna sluzhba statystyky Ukrainy. Available at: https://www.ukrstat.gov.ua/

24. Kharazishvili, Yu. M. (2007). Teoretychni osnovy systemnoho modeliuvannia sotsialno-ekonomichnoho rozvytku Ukrainy. Kyiv: TOV "Polihraf-Konsaltynh", 324.