The efficiency of work of a large part of the motor transport enterprises of Ukraine is unsatisfactory. For the most part, this situation is associated with significant wear and tear of the fixed assets of enterprises, both rolling stock and the production and technical base. One of the ways to solve this problem is technical development. Under modern conditions, technical development requires a systemic approach, which involves a comprehensive renewal of rolling stock and the production and technical base, taking into account all the interrelationships between these subsystems. To solve this problem, a model of technical development of motor vehicle enterprises was developed in the work, which allows to identify promising strategies, and for their implementation to form and research technical development projects. To select the optimal technical development project, the objective function is substantiated in the work, which includes a technical indicator – the technical readiness ratio and economic indicators – net present value and the payback period of the project. The selection of the optimal project is proposed to be carried out on the basis of the «worst case method». Using this method, the weighting coefficients of the objective function criteria were determined, which corresponded to: for the coefficient of technical readiness – 0.333, for the net present value – 0.556, for the payback period – 0.111. Based on the developed models and algorithms, strategies were determined and technical development projects of the Vinnytsia branch of the private enterprise «Avtotranskom» were developed. Based on the developed objective function and the «worst case method» the optimal technical development project among the developed ones was determined. Implementation of this project allows to increase the technical level, work efficiency and competitiveness of the enterprise

Keywords: technical development, rolling stock, production and technical base, technical operation of cars, commercial operation of cars, strategy of technical development, complex motor vehicle enterprise, decision-making, technical readiness, efficiency of use of rolling stock

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MODEL FOR DEVISING AND DEFINING TECHNICAL DEVELOPMENT PROJECTS OF MOTOR TRANSPORT ENTERPRISES

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1. Introduction

Today, a significant number of combined motor transport enterprises, created in Soviet times, are in a difficult technical and economic situation. As a result of transition processes to a market economy that took place after the collapse of the Soviet Union, the global economic crisis of the 2000s, there was a significant decline in the production by industrial enterprises in many sectors of the national economy. Accordingly, the demand for transportation decreased significantly, as a result of which a large part of the offer of motor transport companies became redundant. Trying to solve the current problems, the managers of these motor transport companies quite often made decisions aimed at survival, without thinking about the strategic development of the companies. The sale of rolling stock and production equipment that was effective at that time for nothing leads to the loss of production capacity, investment resources, and qualified personnel, but does not solve the existing problems.

However, after the aforementioned economic crises, with the implementation of reforms, the economy of Ukraine is beginning to recover. The development of production leads to an increase in the volume of transportation, and therefore to the inevitable development of the transport industry. However, the adopted inefficient decisions led the motor transport enterprises to significant physical wear of the main production assets, and especially the rolling stock. Having outdated rolling stock and production and technical base, such motor transport enterprises become uncompetitive. The lack of own resources for development makes it impossible to update these enterprises, and the lack of understanding regarding the development of development projects – the attraction of investments.

Moreover, the events of recent years, namely the Covid-19 pandemic and the full-scale Russian invasion of Ukraine, became an additional negative factor that affected the country's economy as a whole and the transport industry.

One of the ways to solve these problems is the technical development of motor transport enterprises, which involves updating the main production assets, which is based on the optimization of measures for the development of rolling stock and the production and technical base based on the study of the relationships between these subsystems. That is, it is a complex of measures aimed at increasing the efficiency of the operation of the motor vehicle enterprise, based on the optimized simultaneous renewal of the rolling stock with the corresponding necessary measures for the renewal of the production and technical base.

The process of finding strategies and developing projects for the technical development of a motor vehicle enterprise is quite complex because it requires the presence of an effective algorithm and an economic-mathematical model of the functioning of the enterprise during their implementation. At the same time, for each strategy of technical development, several different projects of their implementation may be proposed, which will differ by certain measures of technical development (for example, updating the fleet of cars with different models, etc.). An effective algorithm for substantiating strategies and developing technical development projects will allow for the development of a management solution from the analysis of the current state of the motor vehicle enterprise and the formation of a strategic plan to the adoption of a specific decision on the relevant technical development projects.

Therefore, studies aimed at the development of models and methods for determining optimal strategies and projects of technical development of motor vehicle enterprises under modern conditions are relevant.

2. Literature review and problem statement

Scientific works on the development of motor transport enterprises usually consider either general issues of organization and management of development processes or consider individual components of development separately from others. Most of the work related to technical development considers either the renewal of rolling stock or the improvement of the system of maintaining the rolling stock in a working condition. Although the authors of these works indicate a close relationship between these two problems, there are practically no thorough works that integrate these two problems.

In study [1], the issue of managing strategies of sustainable innovative development of transport enterprises of Ukraine in modern conditions is considered. The authors propose restructuring and transformation of motor vehicle enterprises as a mechanism for implementing the strategy of sustainable development. The work substantiates the system of sustainable development management indicators from the standpoint of preventive anti-crisis management. However, the developed recommendations for the implementation of innovative sustainable development of transport enterprises are too general and do not give an answer as to how to determine this or that strategy. The proposed system of indicators is actually focused on the assessment of management mechanisms, and not on the technical condition of the main production assets.

The problem of choosing cars when updating the fleet of trucking enterprises is considered in [2]. The authors analyzed the existing criteria and methods for choosing the rolling stock of trucks quite well, pointing out the advantages and disadvantages of each of them. As a result, the authors proposed a method of choosing trucks when updating the fleet of motor vehicle enterprises, which eliminates many of the shortcomings of the existing criteria when using them separately. However, the proposed methodology does not consider the issue of maintaining new cars in working order and the problems that may arise at the motor vehicle enterprise. Moreover, not taking into account the state and capabilities of the production and technical base when buying new cars can lead to an incorrect assessment of their operating costs, which can lead to a loss of profitability.

In work [3], the issue of renewal of rolling stock in motor transport associations is considered. However, this method imposes restrictions on the minimum accounting number of rolling stock, which must be at least 200 units. Taking into account the fact that under modern conditions there are almost no motor vehicle enterprises with the number of 200 or more cars, this makes it impossible to apply this method for many existing motor vehicle enterprises. Moreover, this method only allows one to determine the required total carrying capacity of the rolling stock fleet, and the update is performed by any cars of this type produced by the industry, without taking into account their compliance with the existing production and technical base and economic effect.

In work [4], the authors consider the issue of updating the rolling stock of the motor vehicle enterprise, taking into account the attraction of additional investments. The method of updating the rolling stock of a motor vehicle enterprise developed by the authors corresponds to modern economic conditions in Ukraine and makes it possible to assess the impact of economic risks on the overall efficiency of the operation of the motor vehicle enterprise. The main drawback of the work is that when purchasing new cars, the issue of the possibility of maintaining them in working condition is not studied, which, if a significant development of the production and technical base is necessary, will significantly affect the final result.

Paper [5] investigates the issue of readiness of motor transport enterprises for economic development and their financial stability. The authors have developed a two-component methodical approach that makes it possible to optimize the assessment of enterprises' readiness for development based on the calculation of the integral indicator of investment adequacy and the level of material costs. The research carried out by the authors showed that for many motor transport enterprises there is a problem of excessive material costs. This can be explained by the obsolescence of rolling stock and the production and technical base of such enterprises. The main drawback of this approach is that it is based exclusively on financial indicators and does not study the issue of the real technical condition and technological level of rolling stock and the production and technical base of the motor vehicle enterprise.

In [6], a study of the factors affecting the technological equipment of the production and technical base of the motor vehicle enterprise was carried out. Based on the method of expert evaluations, the authors established that the most significant factors in the selection of innovative technological equipment are the productivity of the equipment, the capacity and specialization of the motor vehicle enterprise, and the technical safety of the equipment. However, the work lacks any quantitative and qualitative indicators by which new equipment can be evaluated according to the proposed factors. Therefore, accordingly, it is not clear how this approach will increase the efficiency of the use of rolling stock of a motor vehicle enterprise.

Work [7] considers the diversification of the production activity of a motor vehicle enterprise as a strategy for its development. The author offers two types of diversification strategies. The first type of strategies is related to the development of the transportation system, when a trucking company introduces a new type of transportation that was not performed before. The second type of strategies is aimed at the development of the production and technical base and is related to the provision of car service services. However, when developing the strategy of the first type, the author does not study the issue of the need to develop the production and technical base for the new rolling stock. When developing a strategy of the second type, it is unclear whether the company plans to provide transport services in the future, because the rolling stock remains old and inefficient.

Therefore, our review of the literature revealed the absence of thorough scientific works that consider the problem of technical development of motor vehicle enterprises, which would investigate the interrelationships between the renewal of the component subsystems of these enterprises and could correspond to modern business conditions. This, in turn, requires solving a significant number of scientific and methodological, organizational, technical, and economic tasks related to the formation and implementation of strategies and projects of technical development of motor transport enterprises.

3. The aim and objectives of the study

The purpose of this study is to increase the efficiency of the use of rolling stock of motor transport enterprises based on the definition and implementation of optimal projects of their technical development. This will make it possible to improve the competitiveness and profitability of a motor vehicle enterprise under modern business conditions.

To achieve the set goal, the following tasks must be solved:

– to build a mathematical model of the technical development of motor vehicle enterprises based on a systemic approach, which makes it possible to investigate the interrelationships between the renewal of the rolling stock of motor vehicle enterprises and the corresponding renewal of its production and technical base;

– to justify the criteria for evaluating the effectiveness of projects of technical development of motor transport enterprises;

– to develop an algorithm for modeling projects of technical development of motor vehicle enterprises;

– to justify the method and devise a methodology for evaluating projects of technical development of motor transport enterprises;

– to model technical development projects on the example of the Vinnytsia branch of the private enterprise «Avtotranskom» and determine the optimal one.

4. The study materials and methods

As mentioned above, one of the ways to increase the efficiency of the work of motor transport enterprises under modern conditions is technical development, i.e., updating the main production assets of enterprises, namely their active and passive parts. With regard to motor vehicle enterprises, technical development primarily involves updating the rolling stock with more modern and efficient models of cars, taking into account ensuring their maintenance in working condition.

Thus, the object of our study is the technical development of motor transport enterprises and its influence on the efficiency of the use of rolling stock.

Under market economic conditions, in contrast to planned and administrative ones, technical development requires the use of a strategic approach, which involves looking at the enterprise as an «open» system, the main prerequisites of which are not inside but outside this system. This, in turn, involves the use of strategic management methods to analyze the company's performance and develop technical development strategies.

The definition of the technical development strategy will be carried out based on the results of the modeling of its implementation projects, which involves the use of economic and mathematical modeling of technical development projects with the help of electronic computers. To determine the initial data of the simulation, it is most appropriate to use the methods of mathematical statistics and probability theory. Since the definition of the optimal project of technical development requires an assessment based on several criteria of optimality, it necessitates the application of methods of fuzzy multi-criteria analysis.

5. Results of investigating the technical development of motor transport enterprises

5. 1. Mathematical model of technical development of motor transport enterprises

To study the functioning of complex organizational and technical systems to which a motor vehicle enterprise belongs, and to facilitate decision-making, economic-mathematical modeling has become widely used. An economic-mathematical model is a description of an object (subject, process, or phenomenon) in the form of a set of mathematical expressions (equations, inequalities, etc.), compiled for the purpose of studying its properties. The process of research using a mathematical model is called modeling.

Formal statement of the problem. Let there be a certain motor vehicle enterprise that plans its further development based on the fact that the profit does not increase but remains constant or even decreases. It is necessary to find and justify such a strategy for further development that would increase the efficiency of the motor transport enterprise.

To describe the model, we introduce the following notation:

– $i=\overline{1,s}$ – number of the technical development strategy of the motor vehicle enterprise;

– $j=\overline{1,n}$ – technical development project number within strategy s;

– $k=\overline{1,m}$ – index of brands of rolling stock of the enterprise;

– $t=\overline{1,T}$ – temporary stages of implementation of the technical development project;

– II_{ijk}^{RS} – the initial investment required for the purchase of the k-th type of rolling stock under the j-th project of strategy i;

– II_{ijk}^{PTB} – initial investments necessary for the development of the production and technical base of the enterprise for the k-th type of rolling stock under the j-th project of strategy i;

– P_{ijkt} – profit from the performance of transport work by the k-th type of rolling stock under the j-th project of strategy i in the t-th time period;

– r – discount rate for the term of strategy implementation;

– R_{ijk} – the resource intensity coefficient, which characterizes the need for material resources to perform the transport work of the k-th type of rolling stock according to the j-th project of strategy i;

– K_{ij} – restrictions that may occur during the implementation of the jth project of strategy i;

– W_{ijkt} – volume of transport work performed by the k-th type of rolling stock under the j-th project of strategy i in the t-th time period;

– C_{ijk} – the tariff for the performance of transport work by the k-th type of rolling stock under the j-th project of strategy i;

– C_{ijk}^{av} – the average market tariff for the performance of transport work by the k-th type of rolling stock.

Using the entered notation, we write down a number of the following dependences.

Initial investments required for the implementation of the j-th project of strategy i:

$$II_{ij} = \sum_k II_{ijk}^{RS} + \sum_k II_{ijk}^{PTB}. \quad (1)$$

Necessary resources for the implementation of the j-th project of strategy i:

$$\Delta R_{ij} = \sum_k \sum_t R_{ijk} W_{ijkt}. \quad (2)$$

Total profit from the implementation of the j-th project of strategy i:

$$P_{ij} = \sum_k \sum_t P_{ijkt} \frac{1}{(1+r)^t} - II_{ij} \rightarrow \max. \quad (3)$$

The tariff for the performance of transport services for the transportation of the k-th type of rolling stock should not exceed the average market values because under other conditions this type of transportation becomes uncompetitive for the enterprise. Taking into account this tariff limitation and limitations on the possibility of attracting resources, it is possible to write down a system of limitations when modeling projects of technical development of motor transport enterprises:

$$\begin{cases} W_{ijkt} \geq 0; \\ P_{ij} \rightarrow \max; \\ II_{ij} \leq II_{\max}; \\ \Delta R_{ij} \leq K_{ij}; \\ C_{ijk} \leq C_k^{av}. \end{cases} \quad (4)$$

The above limitations most fully characterize the effectiveness of the possible implementation of the j-th project of the strategy and technical development of the motor vehicle enterprise. As you know, investment projects are associated with attracting additional funds from both internal and external sources, and given the volume of these funds, they are mainly external. The search for external investments is a rather complex process that requires a separate study, and therefore will not be considered further in this study. However, it should be noted that the maximum amount of initial investment attraction objectively also has limitations.

Thus, the set of equations and inequalities (1) to (4) represents a generalized economic-mathematical model of technical development projects of the motor vehicle enterprise.

5. 2. Criteria for determining the optimal project of technical development of a motor vehicle enterprise

Modeling of technical development projects involves the determination of indicators on the basis of which their comparison and selection of the optimal one will be carried out. This, in turn, poses the task of substantiating performance criteria, which will contain indicators that assess both the increase in the technical level of the enterprise and its profitability. Thus, the determination of the optimal technical development project is a multi-criteria optimization task based on the technical and economic indicators of the operation of the motor vehicle enterprise.

In this regard, we justified the use of one technical and two economic criteria for evaluating the effectiveness of technical development projects of motor transport enterprises. As a technical criterion, the use of the coefficient of technical readiness (α_T) is substantiated, as economic criteria – payback period (T_P), and net present value (NPV).

The selection of the optimal project, among the set of possible projects of technical development according to different strategies of technical development, when applying a multi-criteria approach, is carried out with the help of an objective function. In the process of performing the optimization task, such values of the design parameters should be found at which the objective function has a minimum (or a maximum).

For the proposed performance indicators, the optimization objective function can be written as follows:

$$U = f\left(\alpha_T, NPV, T_P\right). \quad (5)$$

At the same time, the change in the main parameters and limitations of the objective function can be defined as follows:

$$\begin{cases} \alpha_T \rightarrow \max; \\ NPV \rightarrow \max; \\ T_P \rightarrow \min; \\ T_P < T_{imp}; \\ NPV > 0. \end{cases} \quad (6)$$

where T_{imp} – planned project implementation period, years.

5. 3. Modeling algorithm

To determine technical development strategies based on the modeling of projects that implement these strategies, it is most appropriate to use mathematical modeling. The essence of the developed model is reduced to the description of the organizational and production processes of the motor vehicle enterprise during the implementation of the relevant technical development projects, which makes it possible to determine the indicators of its work that take place at each time interval. We take the value of the simulation interval equal to one year.

The justification of the strategies is based on the developed modeling algorithm, the generalized block diagram of which is shown in Fig. 1.

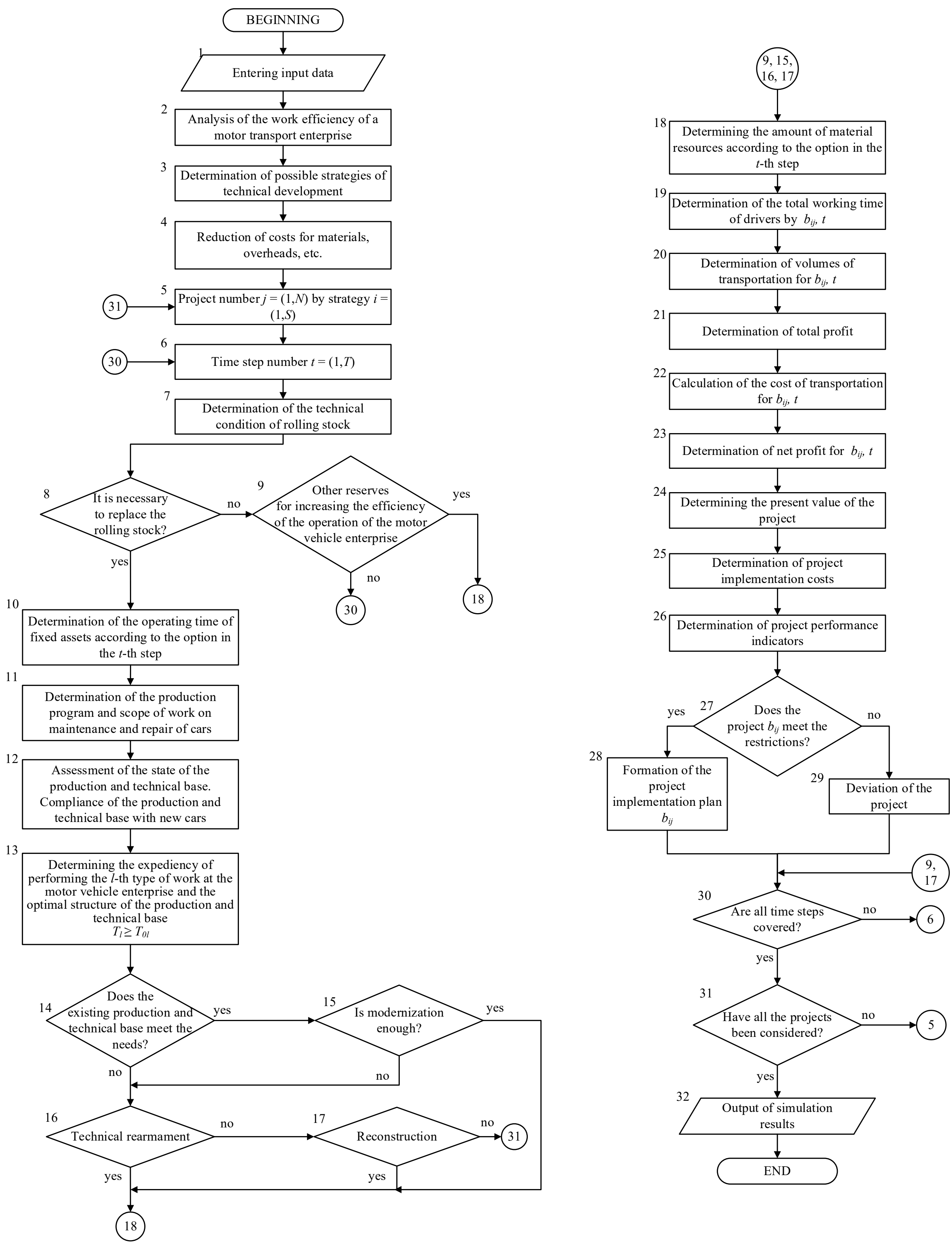

Fig. 1. Algorithm for modeling projects of technical development of motor transport enterprises

Modeling according to this algorithm is as follows:

In module 1, the initial data is entered. First of all, these are data on the number of cars of each brand and their technical and operational characteristics, maintenance, and repair costs. In addition, data on the costs of carrying out transport work, volumes of transport, and the profit that each car brings to the motor transport company are required.

Module 2 performs the procedure of analyzing the efficiency of the motor vehicle enterprise and formulating possible strategies for technical development.

It is expedient to evaluate the efficiency of the enterprise according to known methods of evaluating the production and economic activity of the motor vehicle enterprise [4, 8–12]. It is best to use SWOT analysis to find strategic areas of enterprise management and formulate technical development strategies. It provides an opportunity to investigate the strengths and weaknesses of the motor vehicle enterprise in order to adapt to the changing opportunities and threats of the external environment [13–16].

Based on the data obtained from the implementation of module 2, module 3 formulates the most appropriate strategies for the technical development of the motor vehicle enterprise, which are determined by the markets (or market segments) of transport services for which they are offered. Thus, as a result of the implementation of the given module, we obtain a set of strategies for the technical development S:

$$S=\{s_1, s_2, ..., s_i\}, \qquad (7)$$

where s_1, s_2, s_3, ... , s_i – technical development strategies; i is the technical development strategy number.

Module 4 identifies possible ways to reduce costs for materials and spare parts, overhead costs, etc.

Modules 5 and 6 form project numbers j according to strategy i and time step t, respectively. The project number is assigned depending on both the proposed technical development strategies (directions of development) and alternative rolling stock options that can be used to implement these strategies. Therefore, a double system of designations is used for technical development projects, which consists of the number of the strategy s and the number of the project of the implementation of this strategy i:

$$B=\{b_{11}, b_{12}, ..., b_{1j}, b_{21}, b_{22}, ..., b_{2j}, ..., b_{i1}, b_{i2}, ..., b_{ij}\}, \qquad (8)$$

where b_{11}, b_{12}, ..., b_{ij} – technical development projects; i – strategy number; j is the number of the i-th strategy implementation project (this index is used to identify alternative projects within the same strategy).

Module 7 analyzes the technical condition of the rolling stock of a motor vehicle enterprise.

Module 8 determines the need to replace the rolling stock that is at the motor transport company. In that case, if renewal of the rolling stock is recognized as necessary, then control is transferred to module 10 and the necessary investments for renewal of the rolling stock are determined.

If a decision is made about the impracticality of replacing the fleet of cars, then the management from module 8 passes to module 9, in which the search for other ways of increasing the efficiency of the motor vehicle enterprise is carried out. As a rule, this is a search for internal reserves of cost reduction, so if there is such an opportunity, then control is transferred to module 18, and if there is no such possibility, then control is transferred to module 30.

Module 10 determines the working time of the main means of production according to the project in the t-th step. First of all, it is the operating time of motor vehicles that will be purchased in the future, which determines the total profit of the motor vehicle enterprise. The calculation is based on known productivity formulas [4, 8, 9, 14].

The group of modules 10–17 is intended to determine the path of development of the production and technical base for the implementation of the project b_{ij}. This is quite important because the existing production and technical base was created and developed for the rolling stock that is operated at the enterprise at the present time, and therefore may not meet the needs of new cars.

Determination of optimal measures for the development of the production and technical base is one of the defining issues in the development of technical development projects. Proceeding from the fact that for any technical development project, it is necessary to create an optimal structure of the production and technical base, which ensures the maximum economic efficiency of technical development, measures for the development of the production and technical base are determined. At the same time, it is necessary to take into account the balance between the costs of developing the production and technical base and the cost of maintenance and repair of cars. This can be ensured both through the centralization of production within the motor vehicle enterprise and through cooperation with other motor vehicle and auto service enterprises.

Module 11 calculates the production program of the motor vehicle enterprise for maintenance and repair of rolling stock and the main indicators of the production and technical base according to technical development projects. Based on the results of the calculations, the needs of the enterprise in the areas of the territory, production-warehouse, and administrative-household premises, posts, production workers, technological equipment, etc. are determined.

In module 12, an analysis of the technical condition of the production and technical base of the motor vehicle enterprise is performed, the condition of technological equipment, buildings and structures, provision of areas, posts, technological equipment, the level of mechanization and other indicators of the condition of the production and technical base are analyzed. Based on the results of the calculation and qualitative analysis of the structural and technological requirements of the new rolling stock for the production and technical base, the ability to provide the existing production and technical base to support new cars in a working condition is determined.

Module 13 is designed to determine the optimal structure of the production and technical base, which ensures the greatest intensification of the latter's development. Thus, within the limits of one enterprise, it is not always advisable to perform all types of maintenance and repair work for cars. The optimal structure of the production and technical base should include only those units whose production costs are lower than the costs of paying for the same types of work in cooperation with car service or other motor vehicle enterprises.

Determination of the optimal structure of the production and technical base, in our opinion, should be carried out on the basis of the definition of the limit volume of the l-th type of work (T_{0l}) of maintenance and repair of rolling stock. The value of T_{0l} corresponds to such a volume of work, in which the costs of their implementation at the own production and technical base are equal to the costs of carrying out the same work by a car repair or car service enterprise [14, 17]. Therefore, if the estimated labor intensity for the l-th type of work (T_l) is not less than the corresponding labor intensity T_{0l}, then it will be appropriate to perform this type of work on its own production and technical base. According to the same principle, it is possible to create such a structure of the production and technical base, in which the enterprise will be able to provide certain maintenance and repair services to other enterprises.

Next, modules 14–17 determine the necessary form of development of the production and technical base according to the project, taking into account the determined structure of the rolling stock of the motor vehicle enterprise and the optimal structure of the production and technical base.

Thus, module 14 determines to what extent the existing production and technical base corresponds to the required structure and is sufficiently effective. If the existing production and technical base mostly meets these requirements, then control is transferred to module 15, if not (technologically incompatible rolling stock, outdated equipment, etc.), then control passes to module 16.

If the existing production and technical base is mostly able to provide support for the new rolling stock, then logical operator 15 determines whether it is sufficient for the existing production and technical base to modernize (minor update) the production and technical base. If a decision is made about the need to modernize the production and technical base, then control is transferred to module 18, and if not, then control is transferred to module 16.

Module 16 determines whether it is sufficient to carry out technical rearmament/re-equipment of the production and technical base to meet the needs of the motor vehicle company in servicing and repairing new rolling stock. In the event that there is not enough technical rearmament to maintain the new rolling stock, then control is transferred to unit 17, which checks the conditions of reconstruction. If it is sufficient to carry out this measure, then control is transferred to module 18.

Module 17 checks the conditions for the reconstruction. If the need for reconstruction is met, control is transferred to module 18. Otherwise, control is transferred to module 30.

Also, in modules 10–17, the technical specialist (expert or group of experts) of the enterprise, determining the form of development of the production and technical base, forms a preliminary list of measures for its development. Preliminary volumes of material and other resources are determined for the selected measures of development of the production and technical base. This point is very important since the amount of initial investment in the development of the production and technical base, and accordingly the effectiveness of the technical development project itself, will depend on the accuracy of determining the amount of these funds. Therefore, under certain conditions, it may be appropriate at this stage to involve additional experts from specialized scientific and consulting organizations.

In modules 18 to 23, technical and economic calculations of the efficiency of the company's rolling stock are carried out for each project b_{ij} in terms of brands and according to the corresponding time steps.

Module 24 determines the present value of future cash flows from the implementation of project b_{ij}.

Module 25 determines the total costs for the implementation of the project b_{ij}, that is, the amount of all necessary investments for the implementation of the project (see formula (1)).

Module 26 determines the numerical values of technical and economic indicators of the objective function (5) of substantiation of strategies and definition of projects of technical development of the motor vehicle enterprise.

Logical operator 27 determines whether project b_{ij} meets the limitations of the objective function of substantiating strategies and defining technical development projects, namely $T_P < T_{imp}$, $NPV > 0$, $II \leq II_{\max}$, or not. If at least one of these conditions is not met, then control is transferred to module 29, which screens out this project, if all restrictions are met, then this project is accepted for further consideration, and control is transferred to module 28, which forms a plan for the implementation of the technical development project b_{ij} (or portfolio of technical development) to form a decision.

Modules 30 and 31, respectively, check whether all given time periods and all available projects have been considered. In the event that all time periods or all possible projects have not been considered, control is returned to modules 6 or 5. If all possible projects have been considered, control is transferred to module 32.

Module 32 forms an array of projects B, which were investigated in the simulation process, and outputs the results. Based on the further evaluation of these projects, the optimal strategy of technical development and the corresponding project of its implementation will be determined.

5. 4. Substantiation of the method for choosing the optimal technical development project

Decision-making on determining the optimal development strategy in real production systems takes place under the conditions when the goals, limitations, and consequences of possible actions are not precisely known. The decision-making task, in its general form, can be described by a set of permissible choices (alternatives) and a preference ratio set on this set, which reflects the interests of the decision-maker.

The relationship of preference for a set of alternatives can be described in two ways:

1) using the utility function;

2) in the form of a binary relation of preference. A utility function usually takes the form of mapping a set of alternatives onto a number axis. Not every preference relation and not on any set of alternatives can be described by a utility function. In some cases, this relationship can be described by a finite set of utility functions, and then the relevant decision-making tasks are multi-criteria.

In this case, a set of criteria for choosing the most rational strategy (project) can be represented in the form:

$$C = \{c_1, c_2, ..., c_l\}, \tag{9}$$

where C is a set of criteria for choosing the optimal development strategy (project); c_l – constituent criteria of the set C (objective function); l is the criterion number of the set C (objective function).

Decision-making tasks that use utility functions are mathematical programming tasks. The optimal solution to such problems is the choice of an admissible alternative on which the utility function takes the maximum (minimum) value. Ambiguity in the statement of the mathematical programming task can be contained both in the description of a set of alternatives and in the description of utility functions. Tasks in which many alternatives and (or) utility functions are vaguely described are called tasks of fuzzy mathematical programming.

In decision-making models under conditions of uncertainty, the Bellman-Zade principle [18, 19] is often used, according to which the optimal strategy (project) is determined according to the following principles:

1. Each criterion c_l is given in the form of a fuzzy set defined on the universal set of projects B (8).

2. A fuzzy set of potentially good solutions b_{opt} is formed by intersection of fuzzy sets of criteria.

3. From a fuzzy set of potentially good solutions, the strategy (project) with the highest degree of appropriateness is selected, and this project is optimal.

Based on this, the best strategy (project) is sought within the cross-section ($\cap$) of fuzzy sets of criteria:

$$b_{opt} \in D = c_1 \cap c_2 \cap \ldots \cap c_l. \qquad (10)$$

Expressions (9), (10) are valid in the case when the importance of all the criteria forming the set is the same. If this is not the case, then the Bellman-Zade principle is usually used together with the Saati method of hierarchies [20], which allows finding measures of membership of elements of fuzzy sets using the procedure of pairwise comparisons of projects. Such a method of multi-criteria selection of the best development project under conditions of uncertainty, which is called the «worst case method», is proposed in [19]. The basis of this method is the principle of intersection of fuzzy Bellman-Zadeh criteria and Saati's 9-point scale of linguistic assessments.

In this case, the set of criteria (10) must be written in the form:

$$C = \left\{ (c_1)^{\mu_1}, (c_2)^{\mu_2}, \ldots, (c_l)^{\mu_l} \right\}, \qquad (11)$$

where μ_l is the weight of the criterion μ_l.

Then each criterion $c_l \in C=\{c_1, c_2, \ldots, c_l\}$ should be interpreted as a fuzzy set defined on the universal set of projects $B=\{b_{11}, b_{12}, \ldots, b_{21}, \ldots, b_{ij}\}$ in the form:

$$c_l = \left\{ \frac{(\omega_{11}^l)^{\mu_1}}{b_{11}}, \frac{(\omega_{12}^l)^{\mu_2}}{b_{12}}, \ldots, \frac{(\omega_{ij}^l)^{\mu_1}}{b_{ij}} \right\}, \qquad (12)$$

where ω_{ij}^l are degrees of membership of projects ω_{ij}^l within fuzzy sets c_l.

Degrees of ownership of projects are numbers in the interval [0; 1], which can be considered as project weights relative to the criteria c_l.

At the same time, the condition must be fulfilled:

$$\omega_{11}^l + \omega_{12}^l + \ldots + \omega_{ij}^l = 1. \qquad (13)$$

Based on this, formula (10) will take the form:

$$b_{opt} \in D = (c_1)^{\mu_1} \cap (c_2)^{\mu_2} \cap \ldots \cap (c_l)^{\mu_l}. \qquad (14)$$

In the theory of fuzzy sets, the intersection operation is replaced by the minimization operation: $\cap \rightarrow \min$. Then the set of potentially good solutions will take the form:

$$D = \left\{ \begin{array}{c} \dfrac{\min\left\{ (\omega_{11}^1)^{\mu_1}, \ldots, (\omega_{11}^l)^{\mu_l} \right\}}{b_{11}}, \\ \dfrac{\min\left\{ (\omega_{12}^1)^{\mu_1}, \ldots, (\omega_{12}^l)^{\mu_l} \right\}}{b_{12}}, \ldots, \\ \dfrac{\min\left\{ (\omega_{ij}^1)^{\mu_1}, \ldots, (\omega_{ij}^l)^{\mu_l} \right\}}{b_{ij}} \end{array} \right\}. \qquad (15)$$

The optimal (best) project b_{opt} is the project from the set of potentially good solutions ($b_{opt} \in D$), which has the maximum weight, i.e.:

$$\omega(b_{opt}) = \max_{\substack{i=1,2,\ldots,n \\ j=1,2,\ldots,m}} \min\left\{ (\omega_{ij}^1)^{\mu_1}, (\omega_{ij}^2)^{\mu_2}, \ldots, (\omega_{ij}^l)^{\mu_l} \right\}. \qquad (16)$$

To determine the weight of each project included in the fuzzy set (12), we shall use the method of structural analysis of systems [21], according to which the reliability of the system is distributed among its elements according to the ranks that characterize the importance of the elements from the point of view of reliability. Thus, the sum of project weights (13) will be distributed among projects according to their ranks. Taking this into account, it can be assumed that the higher the weight of the project ω_{ij}^l, the higher its rank q_{ij}^l, i.e.:

$$\frac{\omega_{11}^l}{q_{11}^l} = \frac{\omega_{12}^l}{q_{12}^l} = \ldots = \frac{\omega_{fg}^l}{q_{fg}^l} = \ldots = \frac{\omega_{ij}^l}{q_{ij}^l}, \qquad (17)$$

where q_{ij}^l is the rank of the project $b_{ij} \in B$ in relation to the criterion $c_l \in C$; ω_{fg}^l– the weight of the worst project $b_{fg} \in B$ in relation to the criterion $c_l \in C$; q_{fg}^l is the rank of the worst project $b_{fg} \in B$ with respect to the criterion $c_l \in C$.

Based on relation (19), we represent the weights of all projects in terms of the weight of the worst project:

$$\omega_{11}^l = q_{11}^l \frac{\omega_{fg}^l}{q_{fg}^l}, \omega_{12}^l = q_{12}^l \frac{\omega_{fg}^l}{q_{fg}^l}, \ldots, \omega_{ij}^l = q_{ij}^l \frac{\omega_{fg}^l}{q_{fg}^l}. \qquad (18)$$

The weight of the worst project according to the criterion c_l can be determined from condition (13), substituting the received project weights (18) into it:

$$\omega_{fg}^l = \frac{1}{\dfrac{q_{11}^l}{q_{fg}^l} + \dfrac{q_{12}^l}{q_{fg}^l} + \ldots + \dfrac{q_{nm}^l}{q_{fg}^l}} = \frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{m} \dfrac{q_{ij}^l}{q_{fg}^l}}. \qquad (19)$$

Thus, on the basis of formulas (18) and (19), it is possible to determine the weight of each project through the ratio of the rank of the project q_{ij} to the rank of the worst project q_{fg}. At the same time, the condition $q_{ij}^l / q_{fg}^l \geq 1$ is fulfilled for all values ($i=1, \ldots, n, j=1, \ldots, m$).

To calculate project weights, it is necessary to determine the ratio of ranks q_{ij}^l / q_{fg}^l. For this purpose, the method of paired comparisons by Saati [19, 20] has become widely used in world practice, according to which a rank ratio scale is set for each criterion $c_l \in C$:

$$\frac{q_{ij}^l}{q_{fg}^l} = \begin{cases} 1, \text{if } b_{ij}^l \text{ matches with } b_{fg}^l; \\ 3, \text{if } b_{ij}^l \text{ slightly better than } b_{fg}^l; \\ 5, \text{if } b_{ij}^l \text{ better than } b_{fg}^l; \\ 7, \text{if } b_{ij}^l \text{ much better than } b_{fg}^l; \\ 9, \text{if } b_{ij}^l \text{ absolutely better than } b_{fg}^l; \\ 2, 4, 6, 8 - \text{intermediate values.} \end{cases}$$

By substituting the received rank ratios into formulas (18) and (19), project weights ω_{ij}^l are determined according to the criterion c_l.

Determination of the weight of the criteria μ_l of the fuzzy set (9) is performed on a similar basis. That is, assuming that the higher the weight μ_l of the criterion $c_l \in C$, the higher its rank J_l, by analogy with relation (17), the following equality must be fulfilled:

$$\frac{\mu_1}{J_1} = \frac{\mu_2}{J_2} = \ldots = \frac{\mu_q}{J_q} = \ldots = \frac{\mu_l}{J_l}, \qquad (20)$$

where μ_q is the weight of the least important criterion; J_q is the rank of the least important criterion.

Taking into account the need to fulfill the condition $\mu_1+\mu_2+...+\mu_l=1$ by analogy with (18) and (19), the weight of the least important criterion and other criteria is determined according to the following dependences:

$$\mu_q=\frac{1}{\frac{J_1}{J_q}+\frac{J_2}{J_q}+...+\frac{J_l}{J_q}}=\frac{1}{\sum_{l=1}^{h}\frac{\mu_l}{\mu_q}}; \quad (21)$$

$$\mu_1=\mu_q\frac{J_1}{J_q}, \mu_2=\mu_q\frac{J_2}{J_q}, ..., \mu_l=\mu_q\frac{J_l}{J_q}. \quad (22)$$

The determination of the ratio of criteria ranks is performed according to a similar scale of pairwise comparisons.

By substituting the obtained rank ratios into formulas (21) and (22), we determine the weight μ_l of the criterion c_l.

Fuzzy sets (12) defined on the universal set of projects are formed based on the obtained weights of criteria μ_l and projects μ_l. Next, performing the intersection operation of the obtained fuzzy sets (15), we determine the set of potentially good solutions D and the optimal project according to formula (16).

Taking into account the above methodology, we shall determine the weight of the criteria for the objective function (5) proposed by us. We indicate the criteria:

– c_1 – coefficient of technical readiness;

– c_2 – net present value;

– c_3 – payback period.

The least important criterion of the objective function is the payback period (c_3). Based on Saati's linguistic evaluations $J_1/J_3=3$, $J_2/J_3=5$, $J_3/J_3=1$ and formula (21), its weight will be equal to:

$$\mu_3=\frac{1}{3+5+1}=0.111.$$

The weight of the other criteria of the objective function according to formula (22) will be equal to:

$$\mu_1=\frac{3}{3+5+1}=0.333; \mu_2=\frac{5}{3+5+1}=0.556.$$

Given the weighting coefficients of the criteria, the objective function can be written as the set:

$$C=\left\{\alpha_T^{0.333}, NPV^{0.556}, T_P^{0.111}\right\}.$$

5. 5. Modeling of technical development projects and determining the optimal one

Modeling of technical development projects was carried out on the example of Vinnytsia branch of PE «Avtotranskom».

The assessment of the adequacy of the model was performed on the basis of a comparison of the results of modeling the performance indicators of the private enterprise «Avtotranskom» with actual data for 2017–2020. The simulation results showed a discrepancy of up to 5 %, which indicates that the model corresponds to the real object. After that, the development and modeling of technical development projects of the private enterprise «Avtotranskom» was carried out.

An analysis of work efficiency was conducted for this enterprise, which revealed negative trends in its production and economic activity.

According to the results of the SWOT analysis, the following strategies for the development of the enterprise were proposed:

– strategy 1 – development of transportation of oil products (development of the fleet of gasoline trucks);

– strategy 2 – development of transportation of mineral building materials (development of dump truck fleet).

To implement these technical development strategies, the following technical development projects of the motor vehicle enterprise were proposed:

– project 1. 1 – modernization of the fleet of gasoline trucks with gasoline trucks on the Dongfeng DFZ5250 chassis (capacity 16.5 m^3) – 24 units;

– project 1. 2 – modernization of the fleet of gasoline tankers with DAF FT CF85.430 road trains (semi-trailer gasoline tanker 32 m^3) – 12 units;

– project 1.3 – modernization of the fleet of gasoline trucks due to the purchase of Dongfeng DFZ5250 cars, 12Я units, and DAF FT CF85.430, 6 units;

– project 2. 1 – modernization of the fleet of dump trucks due to the purchase of JAC N350 vehicles (carrying capacity 13 tons) – 20 units;

– project 2. 2 – modernization of the fleet of dump trucks due to the purchase of 15 units of KrAZ-65055 vehicles (carrying capacity 18 tons).

The results of the calculation of efficiency criteria by projects are given in Table 1.

To choose the optimal project, on the basis of the performed scientific and methodological developments, fuzzy sets of potentially good solutions were formed. The least important project according to the criterion α_T is project 1.1, according to the NPV criterion – project 2.2, and according to the criterion T_P – project 1.3. Based on Saati's linguistic assessments, the ratio q_{ij}^l/q_{fg}^l for criteria for the projects is determined (Table 2).

Table 1

Project performance indicators

Indicator	Project 1. 1	Project 1. 2	Project 1. 3	Project 2. 1	Project 2. 2
1. Number and brand of cars to be purchased	Dongfeng – 24 units	DAF – 12 units	DAF – 6 units, Dongfeng – 12 units	JAC N350 – 20 units	KrAz-65055 – 15 units
2. Coefficient of technical readiness	0.86	0.89	0.87	0.90	0.91
3. The amount of investment provided for by the project, euros	1075000	1155000	1124600	854500	714600
– for rolling stock	1020000	1080000	1050000	800000	660000
– for the production and technical base	55000	75000	74600	54500	54600
4. Present value, EUR	1340456.7	1490546.9	1396248.2	1105344.4	898774.5
5. Net present value, euros	265456.7	335546.9	271648.2	250844.4	184174.5
6. Payback period, years	2.67	2.58	2.68	2.57	2.65

Table 2

The ratio of project ranks on the Saati scale

Criterion / Project	α_T	NPV	T_P
Project 1. 1	1	4	2
Project 1. 2	3	7	3
Project 1. 3	2	5	1
Project 2. 1	4	3	3
Project 2. 2	5	1	2

Formulas (21) determine the weight of the worst project according to the criterion c_l, and formula (20) determines the weight of all other projects. The results of our calculations are given in Table 3.

Table 3

Weight of projects by performance criteria (ω_{ij}^l)

Criterion / Project	α_T	NPV	T_P
Project 1. 1	0.0667	0.2000	0.1818
Project 1. 2	0.2000	0.3500	0.2727
Project 1. 3	0.1333	0.2500	0.0909
Project 2. 1	0.2667	0.1500	0.2727
Project 2. 2	0.3333	0.0500	0.1818

Based on this, the weight of each project was determined, taking into account the weight of the criteria $(\omega_{ij}^l)^{\mu_l}$, calculated earlier. The results of our calculations are given in Table 4.

Table 4

Weight of projects taking into account the weight of criteria $((\omega_{ij}^l)^{\mu_1})$

Criterion / Project	$\alpha_T^{0.333}$	$NPV^{0.556}$	$T_P^{0.111}$
Project 1. 1	0.4055	0.4090	0.8274
Project 1. 2	0.5848	0.5581	0.8656
Project 1. 3	0.5109	0.4629	0.7661
Project 2. 1	0.6437	0.3486	0.8656
Project 2. 2	0.6934	0.1893	0.8274

Performing the operation of intersection of fuzzy sets (15) $D=\alpha_T \cap NPV \cap T_P$, we obtain the fuzzy set of the solution:

$$D=\left\{\frac{0.4055}{b_{11}};\frac{0.5581}{b_{12}};\frac{0.4629}{b_{13}};\frac{0.3486}{b_{21}};\frac{0.1893}{b_{22}}\right\}.$$

6. Discussion of results of investigating the technical development of motor transport enterprises

The technical development of the motor vehicle enterprise is aimed at increasing the efficiency of the use of vehicle fleet, which is ensured by the use of more efficient rolling stock and optimization of the structure of the production and technical base. For the implementation of technical development in practice, we developed a mathematical model, a modeling algorithm, substantiated the criteria system and management decision-making methodology. On the basis of scientific and methodological developments, modeling of technical development projects of the Vinnytsia branch of the private enterprise «Avtotranskom» was carried out and the optimal one was determined.

In the course of research, an analysis of the main indicators and results of modeling of technical development projects was performed (Table 1).

As can be seen from Table 2, project 1. 2 has the highest value of the coefficient of technical readiness among the projects according to the strategy for the development of the fleet of gasoline trucks, and project 1. 1 has the lowest. At the same time, project 1. 2 exceeds project 1. 1 by approximately 3 %, which is related with greater reliability of DAF cars compared to Dongfeng cars. The value of the coefficient of technical readiness for project 1.3 is between the two previous projects due to the use of a combined fleet of rolling stock. Among the projects under the dump truck fleet development strategy, project 2. 2 has a higher technical readiness factor, which is approximately 1 % higher than project 2. 1. This is due to the difference in the average daily mileage, which, accordingly, affects the total downtime park in maintenance and repair. For the same reasons, it is impractical to directly compare the coefficient of technical readiness for projects of different strategies.

When comparing the volumes of initial investments by projects (Table 1), it can be seen that the most estimated is project 1. 2. The volumes of its initial investments exceed the volumes of project 1. 1 by 1.07 times, and project 1. 3 by 1.03 times. 1.35 times – project 2. 1 and 1.62 times – project 2. 2. If we compare the net present value of these projects, it will be the largest in project 1. 2, which indicates the greatest commercial effect during its implementation, which will exceed the corresponding amount of project 1. 1 by 26.4 %, project 1. 3 by 23.5 %, project 2.1 by 33.8 %, and almost twice that of project 2. 2.

The payback period of all projects is approximately the same and is within 2.5–3 years (Table 2). Projects 2. 1 and 1. 2 have the lowest values, the values of which are 3–4 % better than other projects. Considering the implementation period of 8 years, such a difference is insignificant.

Analyzing the fuzzy set obtained by formula (15), we can conclude that the best technical development project will be project 1. 2, which provides the enterprise with optimal performance indicators.

It should be noted that under project 1. 2 we receive the most modern rolling stock, which most fully (among projects 1. 1–1. 3) meets the needs of the transportation process, namely: fuel supply to the network of OKKO gas stations in Vinnytsia oblast and neighboring regions. This is due to the fact that although the range of transportation of oil products varies from small to quite long, the average distance of transportation is quite large (about 150 km), which allows project 1. 2 to prevail over project 1. 3, which provides for the use of two types rolling stock for transportation over different distances. That is, the low efficiency of the use of road trains on short distances of transportation in project 1. 2 is compensated by a sufficiently high average distance of transportation, which makes this project, although not ideal, but still the most optimal given the market requirements.

The implementation of technical development strategies allows the enterprise to strengthen its position on the market of transport services and improve its competitiveness. This is primarily achieved by selecting and using a fleet of rolling stock that has higher technical readiness and better meets the conditions of transportation. The purchase of new cars requires enterprises to invest funds in updating or expanding the fleet of rolling stock. In addition, with the purchase of new cars, the issue of VTB development to maintain the rolling stock in working order necessarily arises. These measures require the involvement of additional investments in technical development, which will significantly affect the final result.

In this study, in contrast to [2, 3, 10, 11], the economic efficiency of technical development projects is determined using the net present value method, which, compared to profit or costs, more fully corresponds to modern market conditions. In comparison with work [5], this study showed that taking into account measures to update the production and technical base when updating the rolling stock significantly affects the efficiency of the development of the motor vehicle enterprise.

As a result of the research, a technical development project was developed in the current work, which takes into account the interrelationships between the renewal of rolling stock and the development of the production and technical base of the motor vehicle enterprise. According to the simulation results, it was determined that project 1. 2 is the most effective.

The main drawback of this study is a superficial study of the issue of cooperation in the maintenance and repair of rolling stock of the enterprise with car service or other motor vehicle enterprises. Further research in this area may allow development projects to be formed under the conditions of cooperation or outsourcing of these works, which will allow for the development of more effective measures for the development of the production and technical base. Another shortcoming of this study is a superficial assessment of the availability of attracting investment and other resources during the implementation of technical development projects. However, this problem is studied in detail in other works, for example [4, 5].

7. Conclusions

1. A mathematical model of the technical development of the motor vehicle enterprise was built, which takes into account the interrelationships between the renewal of the rolling stock and the corresponding development of the production and technical base of the enterprise. This model, under conditions of limited resources, allows determining the optimal measures for the systematic renewal of the rolling stock and the production and technical base, providing the enterprise with the greatest profit.

2. The system of criteria, which most fully evaluates the effectiveness of technical development measures, has been substantiated, and the objective function of determining the optimal technical development project of the motor vehicle enterprise was constructed. The objective function includes a technical indicator – the coefficient of technical readiness of the car fleet, and economic indicators – the net present value and the payback period of the project.

3. An algorithm for modeling technical development projects has been developed, which allows identifying promising strategies for technical development and devising effective projects for their implementation under modern economic conditions. This algorithm, using the relationships between the renewal of rolling stock and the development of the production and technical base, allows one to form possible projects for the technical development of the motor vehicle enterprise. As a result of modeling, a number of effective technical development projects are obtained. For each project, performance indicators of the motor vehicle enterprise and the value of efficiency criteria were determined.

4. In order to determine the optimal project of technical development, it is proposed to use the «worst case method», which is based on the principle of Bellman-Zadeh fuzzy sets in combination with Saati's 9-point scale of linguistic assessments. The weighting coefficients of the objective function criteria were determined, which are 0.333, 0.556, and 0.111 for the technical readiness factor, net present value, and payback period, respectively.

5. Using an example of the Vinnytsia branch of the private enterprise «Avtotranskom», modeling of the proposed technical development projects was carried out in order to determine the performance indicators of the enterprise, the criteria for the effectiveness of the objective function, and to determine the possibility of implementing the projects. On the basis of the proposed method of choosing the optimal strategy and technical development project, it was established that the most effective is project 1. 2, which implements the strategy of increasing the company's presence in the market of transportation of petroleum products. Project 1. 2 has the highest value of the net present value and one of the best indicators of the coefficient of technical readiness and payback period among the proposed technical development projects.

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.

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Data availability

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

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