DECISION SUPPORT SYSTEM FOR THE MANAGEMENT OF A VEHICLE SERVICE WORKSHOP

SISTEMA DE APOIO À DECISÃO PARA A GESTÃO DE UMA OFICINA DE SERVIÇO DE VEÍCULOS

SISTEMA DE APOYO A LA DECISIÓN PARA LA GESTIÓN DE UN TALLER DE SERVICIO DE VEHÍCULOS

Evgeniy Kozin
Tyumen Industrial University, Tiumen, (Russia)

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Abstract
The paper presents a methodology for implementing a decision support system for managing a car service workshop. The system operates with current technical indicators and financial results of the enterprise. The user of the system has the opportunity to evaluate the possible parameters of the enterprise when changing one or more target indicators. Different management decisions are offered by the system and ranked according to possibility of their implementation. The result of the system operation is a list of recommended decisions. These decisions will allow to achieve the goal set by the user related to achieving economic benefits or reducing the costs for the operation of the enterprise.

Keywords: Decision support system. Digital twin. Digital enterprise. Simulation. Service station

Resumo
O artigo apresenta uma metodologia de implementação de um sistema de apoio à decisão para a gestão de uma oficina mecânica. O sistema opera com indicadores técnicos atuais e resultados financeiros do empreendimento. O usuário do sistema tem a oportunidade de avaliar os possíveis parâmetros do empreendimento ao alterar um ou mais indicadores de meta. Diferentes decisões de gestão são oferecidas pelo sistema e classificadas de acordo com a possibilidade de sua implementação. O resultado da operação do sistema é uma lista de decisões recomendadas. Essas decisões permitirão atingir o objetivo definido pelo usuário relacionado à obtenção de benefícios econômicos ou redução de custos para a operação do empreendimento.

Palavras-chave: Sistema de apoio à decisão. Gêmeo digital. Empresa digital. Simulação. Estação de serviço.

Resumen
El artículo presenta una metodología para implementar un sistema de apoyo a la decisión para la gestión de un taller de servicio de automóviles. El sistema opera con indicadores técnicos actuales y resultados financieros de la empresa. El usuario del sistema tiene la oportunidad de evaluar los posibles parámetros de la empresa al cambiar uno o más indicadores objetivo. El sistema ofrece diferentes decisiones de gestión y se clasifican según la posibilidad de su implementación. El resultado de la operación del sistema es una lista de decisiones recomendadas. Estas decisiones permitirán alcanzar la meta planteada por el usuario relacionada con lograr beneficios económicos o reducir los costos para la operación de la empresa.

Palabras clave: Sistema de apoyo a la decision. Gemelo digital. Empresa digital. Simulación. Estación de servicio

1. INTRODUCTION

Road transport is a source of generating large amounts of data that could be used to optimize the technological and management processes of motor transport enterprises (Gladilina et al., 2022). The transport strategy of the Russian Federation contains a large number of theses that confirm the relevance of the tasks associated with the use of data for the implementation of predictive analytics and their intellectual analysis (Zakharov et al., 2020). In existing scientific works in related fields, the concepts of "digital twins" and "decision support systems" are used, which increase their potential for application (Erofeev, 2019; Couillard, 1993; Rassudov et al., 2021).

In this regard, the purpose of this study is to increase the efficiency of the motor transport enterprise by developing and implementing a decision support system for managing the technical operation of road transport.

It should be noted that the structure of decision support systems and the principles of their operation are currently interpreted by different authors in different ways, and the general concept of their application and use has not been formed (Barrera, Carrasco, Moreno, 2020; Ates et al., 2021). Therefore, this work has a scientific novelty, which is defined by the following provisions: development of the concept of a decision support system in transport, which synthesizes the methods of managing the technical operation of vehicles and the technical capabilities of the tools for developing and designing software products in the field of working with data; development of principles for the application of a decision support system; development and use within the framework of the decision support system of mathematical models aimed at improving the efficiency of the technical operation of road transport.

The practical significance of the study lies in the development of a software product that allows managers of organizations in the motor transport sector to analyze the consequences of potential management decisions, as well as to search for the best option, taking into account established criteria and restrictions.

Existing scientific works devoted to this topic were analyzed. The work of Lin, Bin and ShiSheng (2017) is devoted to the development of a decision support system for optimizing the aircraft service interval based on real-time sensor readings. In th research of Fagerholt et al. (2010), the theoretical foundations of a system model for the transportation of goods by sea are formed, which allows choosing the optimal one according to a criterion specified by the user among a large number of combinations of options for types of transport and routes. In the works of the authors Dorofeev and Kurganov (2020; 2021), methods of system dynamics are used to create a digital model of a motor transport enterprise. A large number of works are devoted to the creation of information systems for managing the transportation process (Ngai et al., 2012; Grzybowskaa, Barceló, 2012; Kolesnik, Gozbenko, 2007).

2. MATERIALS AND METHODS

The problem of choosing the optimal management solution from a number of existing options belongs to the type of inverse problems of operations research and can be mathematically described as follows:

$$W^* = \max\{W(\alpha, x, \xi)\} \text{ – inverse problem } (x \in X) \quad (1)$$

Where α - given, pre-known factors (conditions for performing the operation), which we will denote for brevity by one letter; x - elements of the solution that depend on us, forming in their totality the solution; ξ – unknown factors; W - efficiency indicator; W* - maximum value W(a, x, ξ) taken over all solutions included in the set of possible solutions X.

The formulation of the problem in general terms is as follows: Under given conditions α, taking into account unknown factors ξ, find a solution x∈X that, if possible, provides the maximum value of the efficiency index W.

Factors such as D - income, Prib - profit, NV - tax payments, Rent - profitability, Vtb - breakeven volume of work, Tok - payback period act as restrictions in decision making. The following indicators are used as particular performance criteria: total costs for the implementation of a management decision C, total complexity of making a decision T, list of actions to implement the solution (description of the solution) θ.

Then the formulation of the problem in relation to the management of a motor transport enterprise: It is required to form a list of solutions (alternatives) that satisfy the established decision maker, criteria (one or more) of efficiency (constraints) {D, Prib, NV, Rent, Vtb, Tok}, and then choose from the generated set of alternatives one or more optimal according to the criteria {C→min, T→min, θ →min }, which are equivalent or prioritized.

Visualization of the decision-making process according to the proposed approach is shown in the Figure 1.

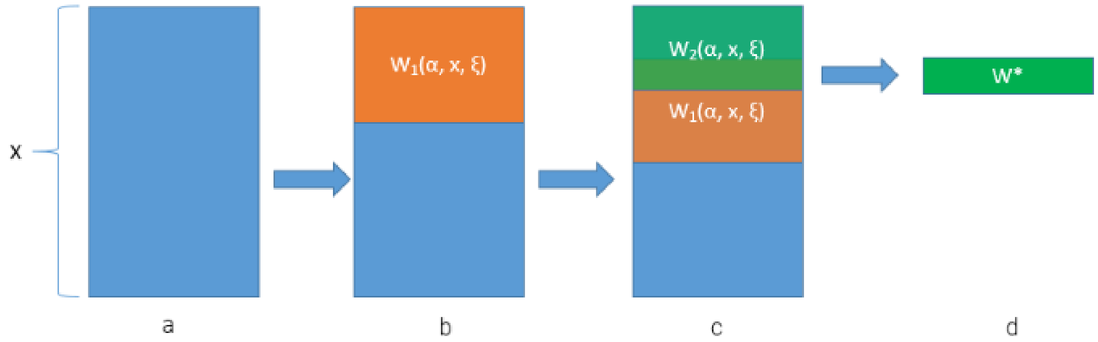

Figure 1. Visualization of the process of obtaining a finite list of alternatives: a - initial set of solutions X; b - selection of solutions by criterion W1; c - selection of solutions according to criterion W2; d - work with the final list of decisions

The principal sequence of actions for making a managerial decision, which is the basis of the proposed approach:

1. Assessment of current parameters and performance indicators of the enterprise;
2. Setting the criterion(s) (objective(s));
3. Formation of a finite list of solutions from an infinite number of possible ones that satisfy the criterion;
4. The choice of one (several) solutions from a finite list for their implementation is a compromise solution (not strictly optimal, but acceptable according to a number of criteria);
5. Heuristic methods for choosing solutions - the formation of statistics on the choice of compromise options and their subsequent automation (selection of weight values a1, a2);
6. Application of deep learning models to automate heuristic approaches by training models on decisions already made by the manager.

The calculation model is based on the technological and economic calculation of a car service workshop (Walker et al., 2022). The methodology for implementing the decision support system for managing the technical operation of the fleet of vehicles is shown in Figure 2 and consists of eight stages.

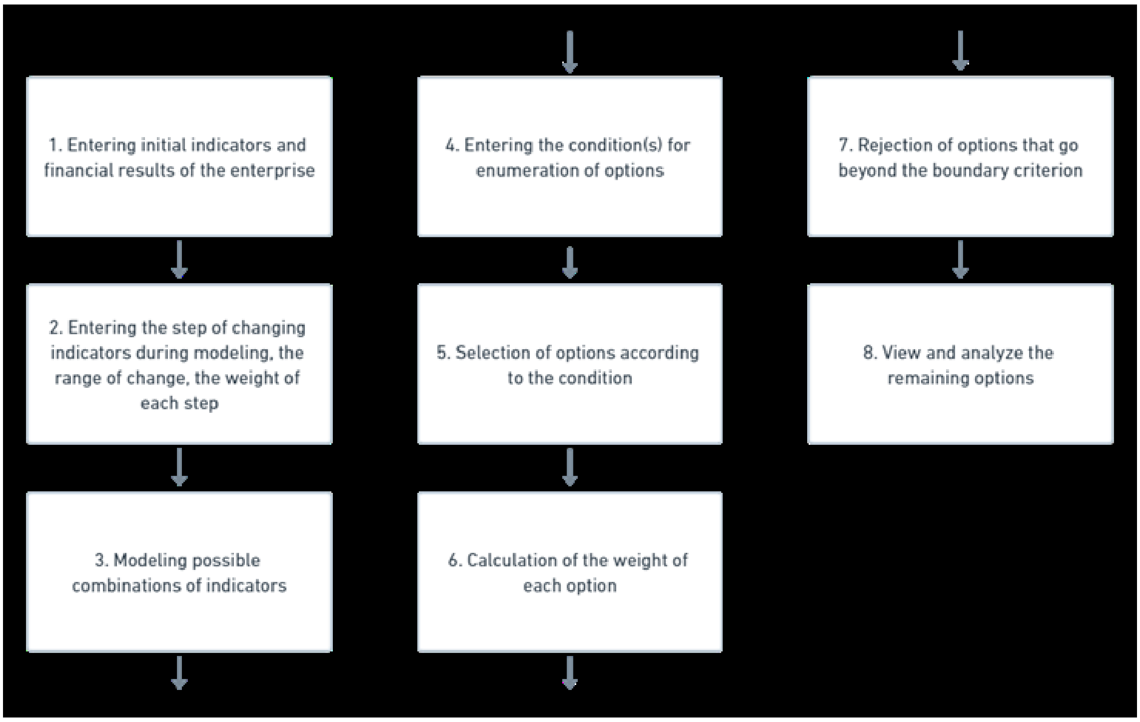

Figure 2. Methodology for implementing a decision support system for managing the technical operation of the fleet

At the first stage, the system receives data on the current technical and financial performance of the enterprise for a reporting period of one year. The list of indicators characterizing the current activities of the enterprise, which are the basis of the calculation model, is presented below: the annual number of vehicles serviced at the service station; number of car-arrivals at the station of one car per year; average annual car mileage; working days in a year; shift duration; number of shifts; commercial cost of a standard working hour; income; profit; total tax deductions; profitability; break-even volume of sales of services; payback period of capital investments (Walker et al., 2022).

This list of indicators is not exhaustive and may vary depending on the specifics of the enterprise.

The window for entering initial data into the system is shown in Figure 3.

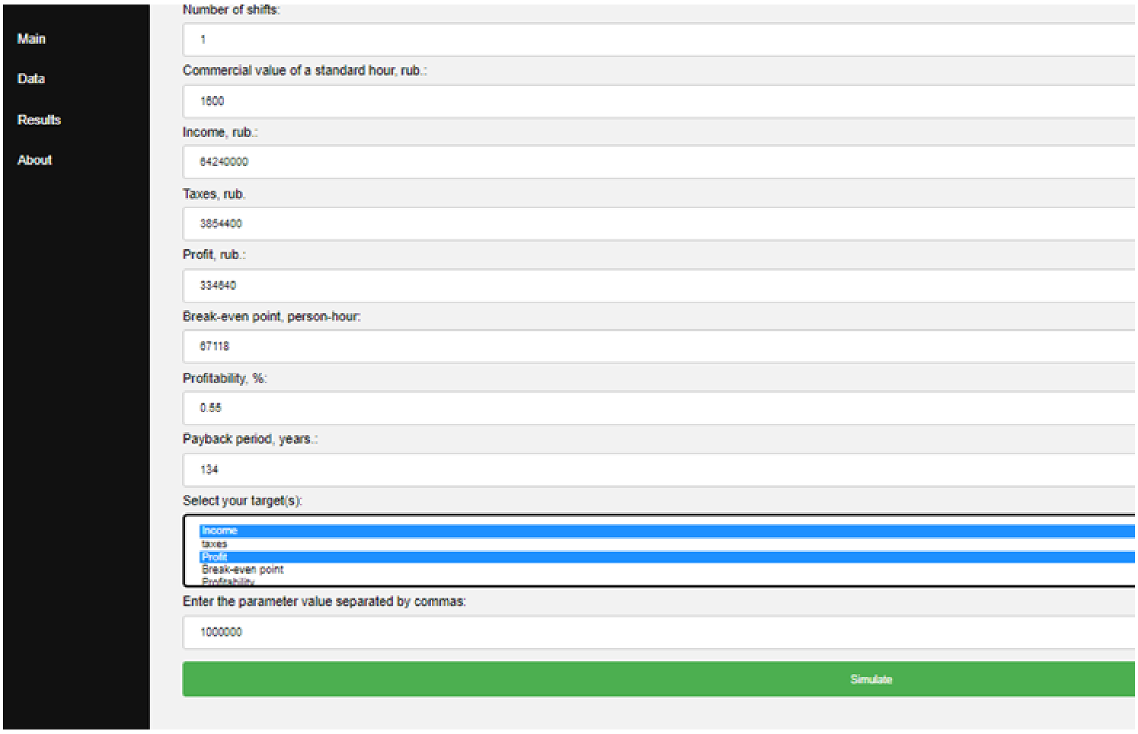

Figure 3. Example of a user interface for a decision support system

For the simulated situation, the user is the director of the enterprise - service workshop (development director), who wants to know what actions can improve the financial performance of the enterprise, for example, profit. The system should provide the user with the parameters of the enterprise, under which it will be able to achieve a given profit value, for example, 1 million rubles. The user can set the values of not only one, but several indicators, as shown in Figure 1, where the profit and payback period of capital investments are selected. After clicking on the "Modeling" button, the calculation module of the system is launched.

The second step is to determine the step and range of change in the initial indicators of the calculation model, the combination of which will be evaluated further. For example, the indicator "Annual number of serviced vehicles at service stations, units." for the underlying design model varies in the range of 100 ÷ 1000 with a step of 100 units. Ranges and steps for changing other indicators are set similarly.

In addition, the model should provide an automated mechanism for comparing options with each other and selecting the most preferred options for the user from the whole variety of possible solutions (Khorolsky, 2022). This mechanism becomes more relevant, the greater the number of options given by the system. Manual analysis of each option out of several hundred presented is a time-consuming and generally unnecessary task for the end user. At the current stage of the study, it is proposed to use the total score of the option as such a mechanism, which is a generalized indicator of the complexity of making a decision for an enterprise, characterizing material, financial, time, labor costs, etc. The larger the value, the less preferred the solution. The score varies from 1 to 5. For example, it is obvious that the option of increasing the annual number of cars serviced at the station by 100 units is more labor-intensive and less feasible for the enterprise than, for example, the option of increasing the length of the working day or the number of working days in year. In the first case, the company bears the costs of marketing and attracting customers, not to mention the possible need to expand the technical capacity of the production base, and in the second case, only additional costs for increasing the wage fund. Therefore, the score for the first option will be higher than for the second, from which the second option seems to be more preferable. The score values are either determined and set by the user based on their own analytics, or the analytics embedded in the system are used.

Table 1 presents the points of change in the values of the initial indicators of the enterprise.

Table 1
Indicators for assessing the deviation of the enterprise indicator from the actual state of the enterprise.

Factor	Score when value changes by 1 step
Average annual car mileage, km.	5
The number of car-arrivals at the station of one car per year, times.	5
Annual number of serviced vehicles at service stations, units	4
Commercial value of a standard hour, rub.	3
Number of shifts, see	2
Working days per year, days	1
Shift duration, hours	1

The formula for calculating the total score for the solution option is presented below:

$$W_{sum}^{i} = \sum_{j=1}^{n} \frac{(V_{jcount}^{i} - V_{jfact}^{i})}{S_j} \cdot R_j$$

where i – is the variant number; Wsum – total weight of the decision’s variant, score; j – the name of the indicator of the enterprise's activity from n indicators; Vcount – calculated value of the indicator; Vf – the actual value of the indicator; S – step of changing the value of the indicator; R – the weight of the indicator change by 1 step.

It should be noted that the total score of the option is determined by comparing it with the actual (current) performance of the enterprise. Thus, when calculating according to formula (1), each option proposed by the system will be characterized by a total score that determines its complexity or feasibility. For example, for a user making a decision, an option rated at 2 points will be more preferable than 10. At the same time, it is possible to minimize the number of options offered to the user for analysis. To do this, it is proposed to use the Pareto method, which, in relation to this study, consists in focusing the user on only 20% of the options distributed by increasing the total score.

At the third stage, the system performs modeling (technological and economic calculation of the enterprise) for all combinations of initial factors formed at the second stage (Stasko et al., 2012). The result of the calculation is the determination of the financial performance of the enterprise listed above.

The user should be able to work only with those options that satisfy the condition of his request to the system. Therefore, the fifth stage is the formation of a custom query from the submitted options (or templates) of queries or the construction of non-standard queries. For example, out of all the presented options, the user wants to receive only those for which the profit will be more than 1 million rubles. A request not formalized into a program form could sound as follows: “Is it possible, by changing any other indicators separately relative to the current level of the enterprise, to achieve a profit of more than 1,000,000 rubles?”.

3. RESULTS AND DISCUSSION

The system selects options according to the condition: profit is greater than or equal to 1 million rubles. As a result, the user receives a set of options divided into categories shown in Fig. 4.

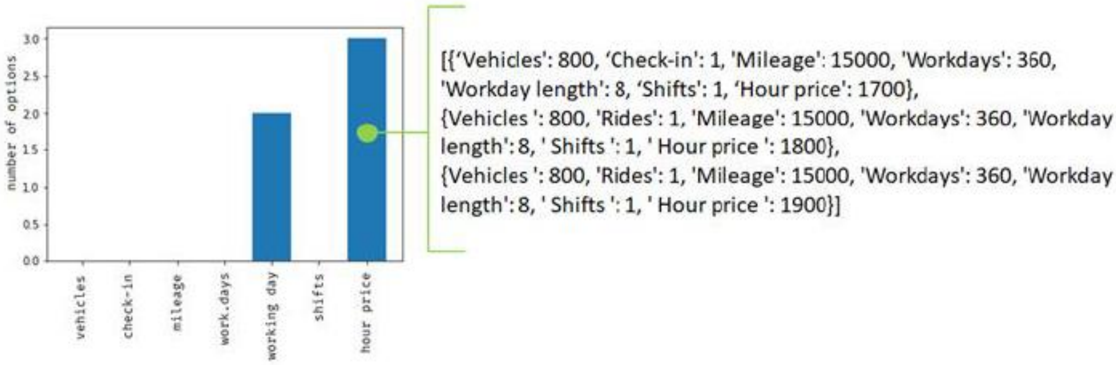

Figure 4. The number of options that correspond to the condition specified by the user, and the content of the options proposed by the system according to the criterion "Commercial cost of a standard hour, rub."

As shown in Fig. In example 3, the system gave the user, at his request, only five options, and 2 solutions are achieved by increasing the working day, and three - by increasing the commercial value of the standard hour of work. The contents of the last group of decision options are also shown in Figure 3 on the right. The user receives a ready-made management solution, which consists in increasing the cost of a standard hour by 100 rubles relative to the current cost of 1600 rubles. Thus, the system made it possible to propose from the general list of options as a solution to this problem the one that meets the user's criteria (Timbario et al., 2011).

However, more informative and practical is the possibility of obtaining solutions while simultaneously changing all the incoming parameters of the enterprise. A specific decision in this case could include changing, for example, three of the seven indicators regarding the current state of the enterprise. In this case, the user's request could be formulated as follows: "Is it possible, by changing any other indicators together relative to the current level of the enterprise, to achieve a profit of more than 1,000,000 rubles?".

The system gives the user a certain number of solutions, distributed according to the degree of increase in their total score at the sixth stage of the methodology. Also, according to the above Pareto method, twenty percent of the options are selected, which will be the final ones. The visualization of the method for selecting options is shown in Figure 5.

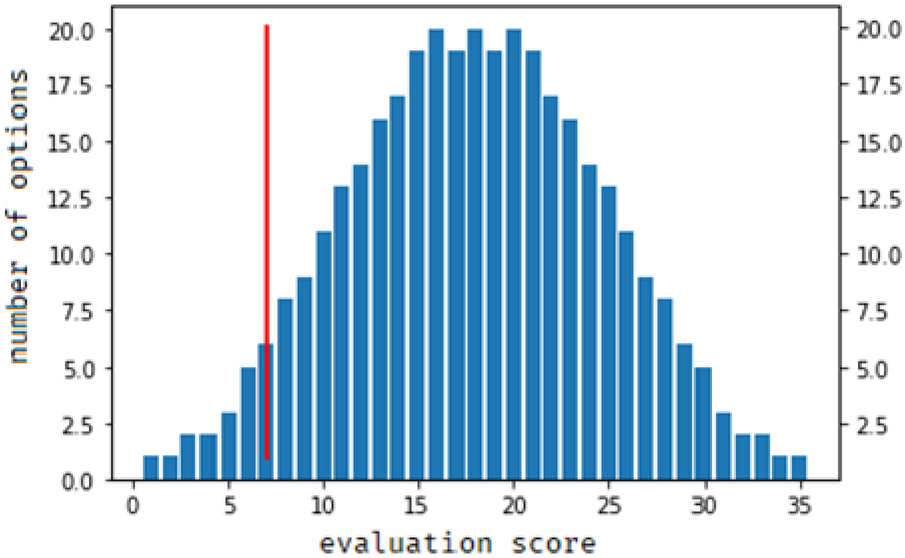

Figure 5. Distribution of the number of options (decisions) that satisfy a given condition, by weights. The red vertical line corresponds to 20% of the total number of options presented

Options that go beyond the boundary criterion can be viewed by the user in manual mode. The final list of options at the seventh stage of the methodology includes only those that satisfy one or more user-specified conditions.

Thus, the last user request for the example under consideration was answered by the system: 352 options, of which 20 solutions were selected according to the Pareto principle for further work and analysis by the user.

The eighth stage is the review and analysis of the final list of options. In this case, the user has the opportunity to run the simulation again, using the parameters of the selected final version as the initial ones (Shikata, Yamashita, Arai, 2019; Zakharov et al., 220). He gets the opportunity to determine how the performance of the enterprise will change within the framework of the selected option in order to more reasonably make a management decision.

In Figure 6 shows a step-by-step process for working with solutions generated by the system.

Figure 6. An example of a windows for outputting final options by a decision support system

At the first step (Figure 5 on the left) there is a derivation of solutions and their evaluation. The system indicates the total number of combinations of options, the number of options that meet the user-specified condition, as well as the number of options for consideration, taking into account the total score of each option, determined by the formula (1). In the same window, the user can analyze the content of each option in more detail (Figure 5 in the center) and model the operation of the enterprise using the parameters of the selected option as input. As a result, the user can predict and evaluate the results of the enterprise if he changes one or more indicators proposed by the system relative to their current value (Figure 5 on the right). Taking into account the above, for the above example, the answer to the last request of the user can be options that involve an increase in the length of the working day by 2 hours, an increase in the cost of a standard hour by at least 100 rubles, or an increase in the number of cars serviced at the enterprise by 100 units.

Further, the program can offer the user a series of actions to achieve the indicator specified in the solution chosen by him. Among the proposed list of actions may be the following: conducting market research; conducting a marketing campaign; carrying out promotions and introducing a system of discounts; improving the quality of work on the service; carrying out the certification procedure; expanding the range of services offered; conclusion of commercial contracts; technical and technological optimization of production; implementation of lean production methods; reducing the labor intensity of car maintenance and repair, etc.

Obviously, each specified action will have different costs of time and money, which the program also informs the user about.

As a practical tool, a program was developed to help decision-making in the management of automotive service. The program is implemented as a web application using the Python programming language and the Django web application design framework. The program uses the initial data of the operating activities of a car service enterprise, which can be entered manually by the user or loaded automatically when integrated with the database of the document management system used at the enterprise. These are data such as the number of car maintenance and repair posts, the number of customers, the length of the working day, the commercial cost of an hour of work, and so on. The user then has to set the goal he want to achieve. As a rule, these indicators are associated with an improvement in the financial performance of the enterprise, for example, with an increase in profits. After that, the program produces a simulation of options for actions through which these indicators can be achieved. The user can select the option manually or leave it to the program, which will reduce the time and select the best option that meets the established criteria. Then the user can analyze the proposed option and simulate the further operation of the enterprise with the parameters specified in the option.

4. CONCLUSIONS

Thus, the structure of the decision-making system for managing the technical operation of the fleet of vehicles was developed. The operation of the system is presented on the example of managing a car service station. The system allows you to predict the parameters of the current and financial activities of the enterprise and form a list of actions to achieve them, taking into account the criteria set by the user. The selection of options is carried out taking into account the total score of each option, which is a generalized indicator of the complexity of implementing a decision regarding the current state of the enterprise. The options distributed according to the degree of increase in the total score are selected according to the Pareto criterion, while the options with the smallest weights (the least complexity of implementation) are offered for consideration by the user. The system is implemented as a web application with the ability to input / output information, implement the functionality of models and interact with databases. The enterprise connects to the system on a subscription basis, synchronizing activity data with the system. Directions for further research are the development and implementation of a methodology for determining the optimal options for the functioning of the system, taking into account the conditions and optimization criteria set by the user; improving the methodology for selecting and substantiating the criteria for comparing options using machine learning methods; adaptation of the block of application models to the conditions of real enterprises with a connection to their databases and dynamic information flows, for example, from transport telemetry systems.

REFERENCES

Ates, K.T.¸ Jahin, C.S., Kuvvetli, Y., Küren, B.A., Uysal, A. (2021). Sustainable production in cement via artificial intelligence based decision support system: Case study. Case Studies in Construction Materials, 15.

Barrera, J., Carrasco, R.A., Moreno, E. (2020). Real-time fleet management decision support system with security constraints. TOP, 28, 728-748.

Couillard, J. (1993). A decision support system for vehicle fleet planning. Decision support systems, 9(2), 149-159.

Dorofeev, A.N., Kurganov, V.M. (2020). Implementation of the concept of "digital twins" for the management of a transport and logistics company, In: Automobile transportation and transport logistics: theory and practice. Collection of scientific works of the department "Organization of transportation and transport management" (with international participation), pp. 26-32. Omsk, Russia.

Dorofeev, A.N., Kurganov, V.M. (2021). Analysis of the activities of a motor transport enterprise using system dynamics. Digital transformation of transport: problems and prospects, In: Materials of the National scientific-practical conference dedicated to the 125th anniversary of RUT (MIIT), pp. 233-238. Moscow, Russia.

Erofeev, A. (2019). Multi-criteria evaluation of management decisions in the intellectual system of transportation management. Open semantic technologies for designing intelligent systems, 3, 205-208.

Fagerholt, K., Christiansen, M., Hvattum, L.M., Trond, A.V., Johnsen, A.V.T., Vabø, T.J. (2010). A decision support methodology for strategic planning in maritime transportation. Omega, 38, 465-474.

Gladilina, I., Pankova, L., Sergeeva, S., Kolesnik, V. (2022). The Effect of Using Information Technologies for Supporting Decision-Making in the Procurement Management of na Industrial Enterprise on Reducing Financial Costs. Indian Journal of Economics and Development, 18(20), 367-373. https://doi.org/10.35716/IJED/22068

Grzybowskaa, H., Barceló, J. (2012). Decision support system for real-time urban freight management, In: The Seventh International Conference on City Logistics Procedia - Social and Behavioral Sciences 39, pp. 712-725.
Khorolsky, V., Anikuev, S., Mastepanenko, M., Gabrielyan, Sh., Sharipov, I. (2022). Synthesis of the structure of an automated power management system in an industrial enterprise. Journal of Management & Technology, 22, 58-72. https://doi.org/10.20397/2177-6652/2022.v22i0.2350
Kolesnik, M.N., Gozbenko, V.E. (2007). Principles of creating an information-planning and control system for road transport. Modern technologies. System analysis. Modeling, 3(15), 46-52.
Lin, L., Bin, L., ShiSheng, Z. (2017). Development and application of maintenance decision-making support system for aircraft fleet. Advances in Engineering Software, 114, 192-207.
Ngai, E.W.T., Leung, T.K.P., Wong, Y.H., Lee, M.C.M., Chai, P.Y.F., Choi, Y.S. (2012). Design and development of a context-aware decision support system for real-time accident handling in logistics. Decision Support Systems, 52, 816-827.
Rassudov, L., Tolstikh, O., Tiapkin, M., Paskalov, N., Korunets, A., & Osipov, D. (2021). Digital Twin Implementation for Accelerating the Development of Flexible Transportation System Control Software. In 2021 IEEE 62nd International Scientific Conference on Power and Electrical Engineering of Riga Technical University, RTUCON 2021 - Proceedings. Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/RTUCON53541.2021.9711704
Shikata, H., Yamashita, T., Arai, K. (2019). Digital twin environment to integrate vehicle simulation and physical verification. SEI Technical Review, 88, 18-21.
Stasko, T. H., & Oliver Gao, H. (2012). Developing green fleet management strategies: Repair/retrofit/replacement decisions under environmental regulation. Transportation Research Part A: Policy and Practice, 46(8), 1216–1226. https://doi.org/10.1016/j.tra.2012.05.012
Timbario, T. A., Timbario, T. J., Laffen, M. J., & Ruth, M. F. (2011). Methodology for calculating cost-per-mile for current and future vehicle powertrain technologies, with projections to 2024. In SAE 2011 World Congress and Exhibition. https://doi.org/10.4271/2011-01-1345
Walker, D., Ruane, M., Bacardit, J., & Coleman, S. (2022). Insight from data analytics in a facilities management company. Quality and Reliability Engineering International, 38(3), 1416–1440. https://doi.org/10.1002/qre.2994
Zakharov, N. S., Makarova, A. N., & Buzin, V. A. (2020). Basic Simulation Models of Car Failure Flows. In IOP Conference Series: Earth and Environmental Science (Vol. 459). Institute of Physics Publishing. https://doi.org/10.1088/1755-1315/459/4/042084.