

**ALGORITHM JUSTIFICATION OF DEPENDENCE "TIME-COST-QUALITY"
INTO LONG-TERM CONTRACTS WITH MAINTENANCE OF ROADS**

**АЛГОРИТМ ОБГРУНТУВАННЯ ЗАЛЕЖНОСТІ «ЧАС-ВАРТІСТЬ-ЯКІСТЬ»
У ДОВГОСТРОКОВИХ КОНТРАКТАХ З УТРИМАННЯ АВТОМОБІЛЬНИХ ДОРІГ**



Zavorotnyi Serhii Mikolaiovych, National Transport University, Omelyanovich Pavlenko St. 1, Kiev, Ukraine 01010, graduate student of transport construction and property management, e-mail: seregazavorotnyi@gmail.com, тел. +380632406670,

<https://orcid.org/0000-0002-2139-8877>

Summary. In this study reviewed the main groups of methods and models the dependency of "time-cost-quality" optimization are considered which can be divided into: mathematical, heuristic, and metheuristic. The main advantages and disadvantages of these methods are presented. Mathematical have a high accuracy of the results, but there is a need to perform a large number of calculations. Heuristic is more simple and understandable than others, but does not provide global optimization. Metheuristic have a sufficient level of accuracy of calculations and rather flexible by combining the previous two methods.

Also, based on the analysis, an optimal method was identified that is currently the most progressive. According to the development trends and benefits, the meta-heuristic method is quite effective. To create the algorithm of justification the dependence of "time-cost-quality", the structure was investigated the innovative "time-cost-quality" tradeoff modeling of building construction project based on resource allocation authors of Wenfa and Xinhua. A detailed analysis of this model allowed us to obtain an equation that can be used to justify the dependence of "time-cost-quality".

Key words: Output and Performance-based Road Contract, maintenance of highways, optimization.

Introduction. Time, cost and quality are the most important criteria of any contract. The relationship between these components, in **Output and Performance-based Road Contract (OPRC)** for maintenance of highways, is a multi-parameter complex task at the expense of a significant period of validity of contracts (in accordance with [1] 5-7 years) and the constant process of maintenance of highways. For successful implementation of long-term contracts, project managers should clearly understand the relationship between these three components, and therefore the success of the OPRS implementation depends very much on the ability to qualitatively optimize the "time-cost-quality" dependency (TCQ). At present there are a sufficient number of methods and models that are proposed for use in civil engineering and construction in general. However, there are no such methods and models for solving this task in the field of maintenance of roads on the basis of OPRS. Paying attention to the current state of highways of Ukraine and the need for a gradual transition from short-term to long-term contracts [1] there is a need to develop an algorithm for justification the dependence of "time-cost-quality" for OPRS of the maintenance of highways.

Materials and methods. Methods and models by which one can justify the dependence of "time-cost-quality" can be divided into: mathematical, heuristic, and metheuristic. At present, the metaheuristic method is more effective to optimize this dependence. Taking into account the advantages of this method, the basis for justifying the dependence of "time-cost-quality" long-term contracts on maintenance of highways served the innovative "time-cost-quality" tradeoff modeling of building construction project based on resource allocation

authors of Wenfa and Xinhua. Analyzing scientific researches it was determined that this issue in scientific sources is almost not covered.

Methods of research: historical, analytical, mathematical.

Results and Discussion. Cost (C) and time (T) are the most important constituents of the contract, but quality (Q) is no less important, especially for maintenance of highways. When performing maintenance of highways on the basis of **Output and Performance-based Road Contract (OPRS)** quality is of great importance, because the quality of the maintenance of highways directly affects the level of traffic safety. Usually time and cost are expressed in numerical expressions, but the quality of specific numeric expressions is not [1], which makes it difficult to possibility optimization these parameters objectively and effectively implement OPRS. At present, there are many methods and models that can solve this task. Every year they have been more and more to improved, which has led to the emergence of three main groups, which can be conditionally divided into [3]: mathematical, heuristic and metaheuristic.

Mathematical methods are based on the definition of the main factors that influence the relationship between time, cost and contract quality in order to formulate a problem in the form of a mathematical model using linear, nonlinear, integer, and dynamic programming. [3,4,5].

Heuristic methods use sequential algorithms designed to determine and adopt the most optimal solution based on the basic principles and requirements of the task [3,5]. These algorithms are very simple and understandable, which allows you to make managerial decisions, but the lack of mathematical reasonableness and lack of global optimization is a big drawback of them. [3,5].

Metaheuristic methods, unlike previous ones, are more flexible and modern thanks to the simultaneous combination of a mathematical and heuristic component. This method is used at different levels of the optimization process, thus ensuring the quality of the results obtained. That is, so-called evolutionary algorithms are created. Analyzing foreign and domestic studies, one can conclude that the genetic algorithm has become widespread [3-5].

Methods and models for optimizing time, cost and contract quality are shown in Fig. 1.

As we see, there are a number of methods and models that allow you to optimize the time, cost and quality of contracts. Among the leading specialists there is a great tendency to use metaheuristic methods.

To date, there are many models built on the basis of the meta-heuristic method. The authors [2] state that there are about 23 effective methods for optimizing time and cost of contracts for 2013. In recent years, the most widely used genetic algorithm (GA), on the basis of which were created: algorithm for optimizing "particle swarm" by Yang I.T. [6]; the optimization algorithm of "anticipate colony" by the authors of Xiong Y. and Kuang Y. [7] and Ng S.T. and Zhang Y. [8]; the algorithm of "finding harmony" by Geem Z. W. [9]. Leu S. and Yang S. [10] have developed a multi-criteria optimization model for construction projects, but this model required a large number of calculations, which complicated its use.

The disadvantage of later models is the failure to consider quality as an optimization criterion, but modern requirements and statistical studies have shown that quality is a very important indicator of the contract, and for the OPRS, it can be said, even the weekend. El-Rayes K. and Kandil A. [11], on the basis of GA, have developed a multi-purpose model to find the optimal way of using resources in order to minimize the time and cost of providing the maximum level of project implementation quality [2].

Attention is drawn to the fact that time, cost and quality (TCQ) are the most important and at the same time the most controversial goals of construction projects, Wenfa Hu and Xinhua He [2], to solve the optimization problem, TCQ has been proposed an innovative time-cost-quality tradeoff modeling of building construction project based on resource allocation. This model is based on the structural division of the project (contract) into work, time, cost and quality of which will depend on such resources as: construction works (labor costs of workers) (L); materials and products (M); equipment and machinery (E) and administration (A) [2] (table 1). Then, for each resource, time, cost, and quality are indicated, which are eventually summed up. That is, the idea of this model is to continuously interact and influence each other's resources of project through the prism of TCQ.

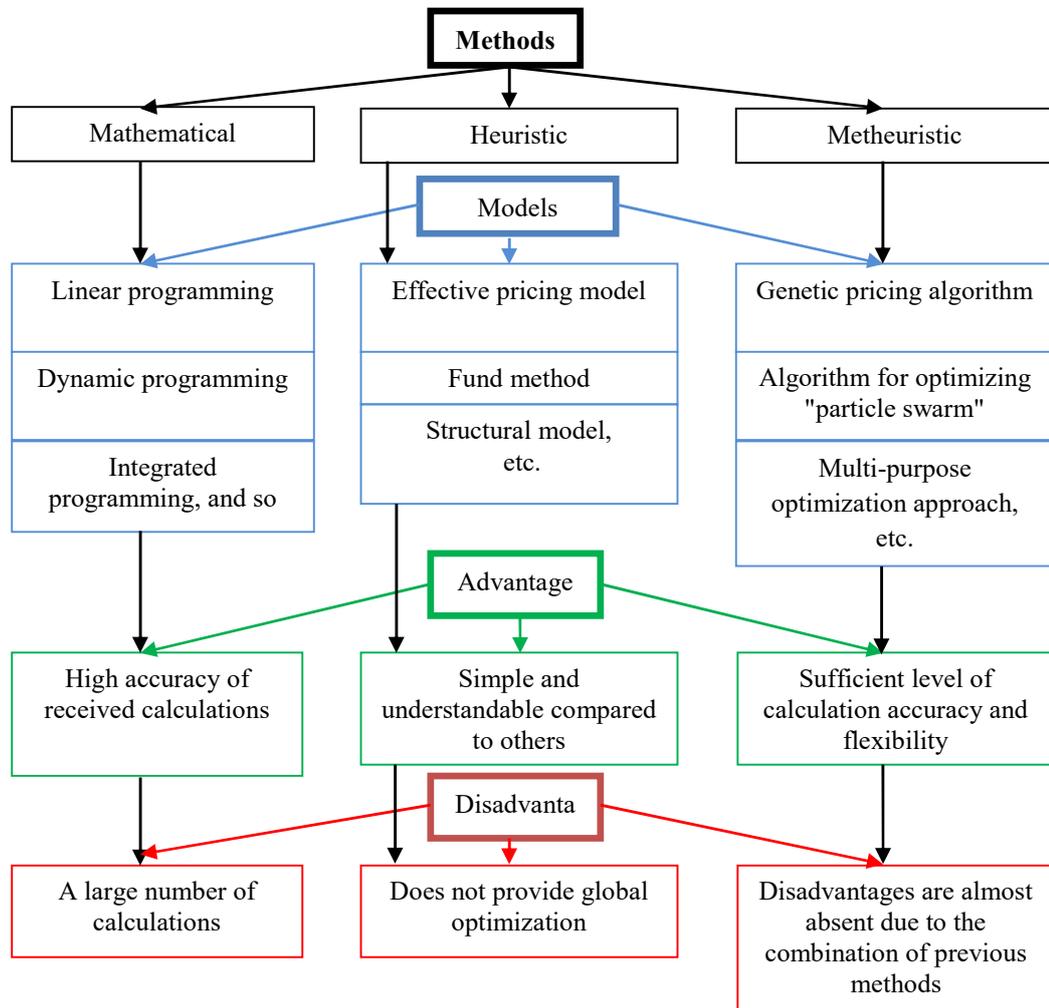


Figure 1 – Methods and models of time optimization, cost and contract quality

Рисунок 1 – Методи та моделі оптимізації часу, вартості та якості контрактів

The process of TCQ interconnection is proposed to be described by the function (1) [12, 13]:

$$F = \begin{cases} Xef(x_1; x_2; x_3; x_4; x_5) \\ Yef(y_1; y_2; y_3; y_4; y_5; y_6), \\ Zef(z_1; z_2; z_3) \end{cases} \quad (1)$$

where, X - optimized value of time (T); Y - optimized value of cost (C); Z - optimized value of quality (Q); x1 - duration of performance of main (planned) works; x2 - the duration of unplanned and auxiliary works;

x3 - feature climatic and soil-geological conditions; x4 - speed of work of the personnel; x5 - delay; y1 - the cost of logistics; y2 - cost of execution of works; y3 - level of complexity of work execution; y4 - fines and incentive payments; y5 - inflation; y6 - the quality of contract financing; z1 - state requirements; z2 - consumer requirements; z3 - international requirements and norms.

Similarly, the authors [2] performed the distribution of their model. For each resource, it is proposed to determine the most important indicators (factors): labor productivity, labor costs, labor complexity, quality of work, cost of materials, quality of materials, productivity of construction equipment, construction equipment cost, amount of construction equipment, quality of construction equipment, cost of administration, quality administration (table 1). To solve the TCQ optimization problem, the contract is represented by a network-based activity-on-node model in which n is defined as a specific action or asset and described as an acyclic graph (5) [2]:

$$G = (A), \quad (5)$$

where, $A = \{0, \dots, n + 1\}$ - the number of nodes (actions, assets); P is the sum of all paths in the network activity-on-node. Starting from 0 and ending with $n + 1$; P_l is the sum of the actions (works, assets) that are on the path $l \in P$.

Table 1 – Structure an innovative time-cost-quality tradeoff modeling of building construction project based on resource allocation (adapted from [2])

Таблиця 1 – Структура інноваційної моделі оптимізації часу, вартості та якості проектів будівництва на основі розподілу ресурсів (адаптовано з [2])

Project (Contract)							Total Σ
Works							
Work k (1)	Work (...)	Work (i)				Work (...)	
Resource							
..	..	Labor force (L _i)	Building materials and products (M _i)	Construction equipment (E _i)	Administration of works (A _i)	..	
Key indicators (factors) of resources							
..	..	-productivity; -the cost of labor; -complete work; -quality of work.	- the cost of materials and products; -quality of materials and products	- productivity of construction machinery; - the cost of construction machinery; - number of construction equipment;	-administration cost; -quality of administration	..	
Time-Cost-Quality							
..	..	Time (i)				..	
..	..	Cost L _i (i)	Cost M _i (i)	Cost E _i (i)	Cost A _i (i)	..	Σ Cost
..	..	Quality L _i (i)	Quality M _i (i)	Quality E _i (i)	Quality A _i (i)	..	Σ Quality

To further construct the model, it is necessary to determine the interaction between the indicators of resources that have the greatest impact on the time, cost and quality of the contracts (projects). According to the authors [2], for the following resources, the interaction of the following factors will be most influential:

1. Labor force (L). For this resource, the most important relationship is the relationship between productivity (P_L) and quality of work (Q_L). To determine this interaction we use formula (6):

$$P_{L(i)} = P_{L_i}^{max} - P_{kL_i} \times (Q_{L(i)} - Q_{L_i}^{min}), \quad (6)$$

where, $Q_{L(i)}$ - the actual level of work quality (i), involved in activities (i), $Q_{L(i)} \in (Q_{L_i}^{min}, Q_{L_i}^{max})$; $Q_{L_i}^{min}, Q_{L_i}^{max}$ - minimum and maximum level of work quality (i), involved in activities (i); $P_{kL_i} = (P_{L_i}^{max} - P_{L_i}^{min}) / (Q_{L_i}^{max} - Q_{L_i}^{min})$; $P_{L_i}^{min}, P_{L_i}^{max}$ - minimum and maximum level of labor productivity (i) involved in activities (i); $P_{L(i)}$ - factual level of labor productivity involved in activities (i), involved in activities i (i), $P_{L(i)} \in (P_{L_i}^{min}, P_{L_i}^{max})$.

2. Building materials and products (M). This resource will depend on the relationship between the cost of materials and products (C_M) and their quality (Q_M). The relationship between the cost of materials and their quality can be described by the formula (7):

$$C_{M(i)} = C_{M_i}^{min} - C_{kM_i} \times (Q_{M(i)} - Q_{M_i}^{min}), \quad (7)$$

where, $Q_{M(i)}$ - is the actual quality level of materials (i), $Q_{M(i)} \in (Q_{M_i}^{min}, Q_{M_i}^{max})$; $Q_{M_i}^{min}, Q_{M_i}^{max}$ - minimum and maximum quality of materials (i); $C_{kM_i} = (C_{M_i}^{max} - C_{M_i}^{min}) / (Q_{M_i}^{max} - Q_{M_i}^{min})$; $C_{M_i}^{min}, C_{M_i}^{max}$ - minimum and maximum cost of materials in activity (i); $C_{M(i)}$ - s the actual cost of the materials involved in the activity (i), $C_{M(i)} \in (C_{M_i}^{min}, C_{M_i}^{max})$.

3. Construction equipment (E). For construction equipment and machinery, important factors will be: the performance of construction equipment (P_E) its cost (C_E) and quality (Q_E). Since construction equipment is a factor that greatly affects the time, quality and cost of the project implementation, it is necessary to introduce a modification coefficient which takes into account the impact of this technique on time (8) [1]:

$$P_{(i)} = P_{L(i)} \times F_{mod(i)}, \quad (8)$$

where, $P_{(i)}$ - actual productivity in activit (i); $F_{(i)}$ - modification factor of labor productivity (i) due to change of parameters of construction equipment; $P_{L(i)}$ - labor productivity in activity (i).

The modification factor can be obtained from the quality of equipment (9):

$$F_{mod(i)} = F_i^{min} + F_{kM_i} \times (Q_{E(i)} - Q_{E_i}^{min}), \quad (9)$$

where, $F_{mod(i)}$ - modification factor of productivity of activity (i); $P_{E(i)}$ - labor productivity in activity (i); $F_{kM_i} = (F_i^{max} - F_i^{min}) / (Q_{E_i}^{max} - Q_{E_i}^{min})$; $Q_{E_i}^{min}, Q_{E_i}^{max}$ - max - minimum and maximum quality of construction machinery and equipment (i) in the activity (i).

In order to determine the relationship between the quality of equipment and its cost, Wenfa Hu and Xinhua He used the same linear dependence as for materials and products (formula 7) (10):

$$C_{E(i)} = C_{E_i}^{min} - C_{kE_i} \times (Q_{E(i)} - Q_{E_i}^{min}), \quad (10)$$

where, $Q_{E(i)}$ - is the actual level of construction equipment quality (i) in the activity (i), $Q_{E(i)} \in (Q_{E_i}^{min}, Q_{E_i}^{max})$; $Q_{E_i}^{min}, Q_{E_i}^{max}$ - minimum and maximum level of quality of construction equipment (i) in the activity (i); $C_{kE_i} = (C_{E_i}^{max} - C_{E_i}^{min}) / (Q_{E_i}^{max} - Q_{E_i}^{min})$; $C_{E_i}^{min}, C_{E_i}^{max}$ - minimum and maximum cost of construction equipment (i) in the activity (i); $C_{E(i)}$ - the actual cost of the construction equipment involved in the activity (i), $C_{E(i)} \in (C_{E_i}^{min}, C_{E_i}^{max})$.

It is known that on a building site, and especially on sections of roads where maintenance is carried out, there is a need for overtime work (as, for example, cleaning snow cover from the travel part 24 hours a day), which in turn reduces labor productivity and increases cost [2]. That is, in order to objectively determine the cost of work in this case, it will be necessary to use the coefficient of change in the cost of construction equipment for overtime work α_i [2] (11):

$$\begin{aligned} C_{E(i)} &= (C_{E_i}^{min} - C_{kE_i} \times (Q_{E(i)} - Q_{E_i}^{min})) \times \alpha_i = \\ &= (C_{E_i}^{min} - C_{kE_i} \times (Q_{E(i)} - Q_{E_i}^{min})) \times (1 + (D_{t(i)} - 1) \times S_{d_i}), \end{aligned} \quad (11)$$

Administration of works (A). For administration the most important is the relationship between quality (Q_A) and cost (C_A) work management (12):

$$C_{A(i)} = C_{A_i}^{min} - C_{kA_i} \times (Q_{A(i)} - Q_{A_i}^{min}), \quad (12)$$

where, $Q_{A(i)}$ - is the actual level of administration of work (i) in the activity (i), $Q_{A(i)} \in (Q_{A_i}^{min}, Q_{A_i}^{max})$; $Q_{A_i}^{min}, Q_{A_i}^{max}$ - minimum and maximum level of quality of administration of work (i) in activity (i); $C_{kA_i} = (C_{A_i}^{max} - C_{A_i}^{min}) / (Q_{A_i}^{max} - Q_{A_i}^{min})$; AC_i^{min}, AC_i^{max} - minimum and maximum cost of administering work (i) in activity (i); $C_{A(i)}$ - the actual cost of administering work (i) in activity (i), $C_{A(i)} \in (C_{A_i}^{min}, C_{A_i}^{max})$.

We have determined that during the time of overtime, the cost of construction equipment for the corresponding work increases. The cost of administering works, in this case, will also increase, therefore, in order to objectively determine the cost of administering work in overtime, it is necessary to introduce an appropriate coefficient of increase in the cost of administering work in overtime β_i [2] (13):

$$\begin{aligned} C_{A(i)} &= (C_{A_i}^{min} - C_{kA_i} \times (Q_{A(i)} - Q_{A_i}^{min})) \times \beta_i = \\ &= (C_{A_i}^{min} - C_{kA_i} \times (Q_{A(i)} - Q_{A_i}^{min})) \times (RT_i + 1 - \frac{RT_i}{D_{t(i)}}), \end{aligned} \quad (13)$$

where, β_i - coefficient of change in the cost of administration for overtime work (associated with an increase in the number of used construction equipment and equipment); $\beta_i = (RT_i + 1 - \frac{RT_i}{D_{t(i)}})$; RT_i - hourly rate of administration of work in overtime (we accept equal to 2.0 [2]).

For the final completion of the definition of the basic model interrelations, it is necessary to determine how the work force affects the time of activity (work) and vice versa. To determine the time it takes to realize a particular activity, you need to know the amount of work, the actual productivity of the work and the factors that determine the overtime work or not (14):

$$T_{d(i)} = V_{d(i)} / P_{d(i)} \times D_{t(i)}, \quad (14)$$

where, $T_{d(i)}$ – time of implementation of activity (i); $V_{d(i)}$ – volume of activity (i); $P_{d(i)}$ – actual performance in activity (i); $D_{t(i)}$ – coefficient of overtime work, $D_{t(i)} \in [1,0,1,5]$ – if overtime work is performed from 0 to 4 hours per day (since the working day is 8 hours per day), $D_{t(i)} = 1.0$ – if there are no overtime work.

The cost of labor is determined by the cost of activity (i) and the overtime work (if any) (15):

$$\begin{aligned} C_{L(i)} &= C_{t_i}^S \times T_{d(i)} + (D_{t(i)} - 1) \times (C_{Dt(i)} \times C_{t_i}^S) \times T_{d(i)} = \\ &= C_{t_i}^S \times T_{d(i)} \times \left[1 + (D_{t(i)} - 1) \times C_{Dt(i)} \right] = \\ &= (C_{t_i}^S \times V_{d(i)}) \times ([P_{L_i}^{max} - P_{kL_i} \times (Q_{L(i)} - Q_{L_i}^{min})] \times \\ &\times [F_{mod_i}^{min} + F_{kM_i} \times (Q_{E(i)} - Q_{E_i}^{min})])^{-1} \times (C_{Dt(i)} + 1 - C_{Dt(i)} / D_{t(i)}), \end{aligned} \quad (15)$$

where, $C_{L(i)}$ – cost of labor in activity (i); $C_{t_i}^S$ – cost of work per unit of time (example: day) of activity (i); $C_{Dt(i)}$ – the coefficient of taking into account the cost of work activities (i) in the extraordinary time (we accept equal to 2.0 [2]).

Having determined the basic relationships of the indicators (factors) of resources, one can finally describe the model. To do this, we will describe the formulas that help determine the time (formula 16), cost (formula 17) and quality (formula 18):

1. Total time (T):

$$T = \max_{i=1,n}(t_{est(i)} + T_{d(i)}), \quad (16)$$

where, T – total duration of the project (contract); $t_{est(i)} = \max_{h=1,i-1}(t_{est(h)} + T_{d(i)})$, early start of activity (i) early start of activity (i) which corresponds to the end of previous work and the first $t_{est_1} = 0$.

2. Total cost (C):

$$C = \sum_{i=1}^n (C_{L(i)} + C_{M(i)} + C_{E(i)} + C_{A(i)}), \quad (17)$$

where, C – total cost of work; $C_{L(i)}$, $C_{M(i)}$, $C_{E(i)}$, $C_{A(i)}$ – the cost of works, materials and products, construction equipment, administration of activity (i); n – quantity of works.

3. Total quality (Q):

$$Q = \sum_{i=1}^n (g_i \times Q_{total(i)}), \quad (17)$$

where, Q – total quality of the project; n – quantity of works in the project; g_i – quality score for each activity (i), $\sum_{i=1}^n WT_i = 1.0$; $Q_{total(i)}$ – the quality of the activity (i), calculated taking into account the quality of work, materials and products, construction equipment, administration, $Q_{total(i)} = L_{WT_i} \times Q_{L(i)} + M_{WT_i} \times Q_{M(i)} + E_{WT_i} \times Q_{E(i)} + A_{WT_i} \times Q_{A(i)}$; L_{WT_i} , M_{WT_i} , E_{WT_i} , A_{WT_i} – indicators of quality of works, materials and products, construction equipment, administration of activities (i); $Q_{L(i)}$, $Q_{M(i)}$, $Q_{E(i)}$, $Q_{A(i)}$ – quality of work, materials and products, construction equipment, administration of activities (i).

Having defined the total time, cost and quality of the project (contract), you need to specify the conditions (boundaries) of the task. A contract can only be successfully implemented if it is executed in minimal time in accordance with the requirements for the quality of work (DBN, DSTU, etc.) and without over-spending of funds, ie within the limits specified in the budget contract [2,3]. Based on these requirements one can form the main conditions (boundaries) of the model (18):

$$\begin{aligned} \min \quad & Z_1 = T, \\ \text{s. t.} \quad & C \cdot X \leq A; Q \cdot X \geq B, \end{aligned} \quad (18)$$

where, A – maximum cost; B - minimum requirements for the quality of work; $X = [D_{t(1)} \dots D_{t(n)} Q_{L(1)} \dots Q_{L(n)} Q_{M(1)} \dots Q_{M(n)} Q_{E(1)} \dots Q_{E(n)} Q_{A(1)} \dots Q_{A(n)}]_{1 \times 5n}^T$ – vector of all variables of the model.

After defining all the data and setting the terms of the task, you must choose a method by which you can solve the multi-purpose task of optimizing time, cost and quality. In this and previous articles, we have already noted that for our purposes, the genetic algorithms are the most effective in our opinion [3,14]. For this model authors [1] also used the genetic algorithm, as a method of solving the optimization problem.

In [1], the authors proposed a model for construction projects, which determines the features of the model. It should be noted that this model was not used in the maintenance of roads on the basis of OPRS. By analyzing this model and comparing with the factors that we determined in [12, 13], an attempt will be made to use an innovative model to optimize the time, cost and quality of construction projects for maintenance of roads, taking into account all the features of this process.

Conclusions and Recommendations:

1. For the successful implementation of long-term contracts, the task of optimizing the "time-cost-quality" ratio must be solved. In modern scientific literature, many methods and models are considered, the purpose of which is to solve this tasks. These methods and models can be divided into: mathematical, heuristic, and metheuristic.

2. Based on the analysis conducted, it can be concluded that the issues of optimization of the "time-cost-quality" ratio, for maintenance of roads, had not risen before. Given the current state of motor roads in Ukraine, the requirements for their operational status and the need for the transition from short-to-long-term contracts for maintenance of roads, there is a need to create a modern optimization model to justify the "time-cost-quality" relationship in the contracts of maintenance maintenance of highways based on the final indicators.

3. In this study, an innovative model for optimizing the time, cost and quality of construction projects based on resource allocation, the authors of Wenfa Hu and Xinhua He, was taken as the basis for the creation of the model. This model is based on the structural division of the project (contract) into work, the time, cost and quality of which will depend on such resources as: construction work (labor costs of workers) (L); materials and products (M); equipment (E) and administration (A). However, it should be noted that this model is effective for optimizing the time, cost and quality of projects in civil engineering, and for the maintenance of roads, this model has not been used before. Therefore, there is a need for a more detailed consideration of the innovative model and its possible improvement, adaptation or addition, in accordance with the requirements and needs of the current state of the maintenance system of Ukrainian highways.

4. In our opinion, an innovative model for optimizing time, cost and quality of projects on the basis of resource allocation is the most optimal and progressive for use as a basis for optimizing the time-cost-quality ratio of operational maintenance of highways on the basis of Output and Performance-based Road Contract.

References

1. State target economic program for the development of public roads of state importance for 2018-2022 years. [Electronic resource]. - Access mode: <http://zakon.rada.gov.ua/laws/show/382-2018-%d0%bf>. (Ukr)

2. Wenfa Hu¹, Xinhua He. An Innovative Time-Cost-Quality Tradeoff Modeling of Building Construction Project Based on Resource Allocation. Hindawi Publishing Corporation. Scientific World Journal Volume 2014, Article ID 673248, 10 pages.
3. Zavorotnii S. M. Analysis of methods of optimization of ratio «time – value» to implement performance based road maintenance contracts / S. M. Zavorotnii, A. M. Kharchenko // Highways and Road Construction. - К .: NTU, 2017. - Vol. 101. (Ukr)
4. Jorge M-M. Multiobjective Genetic Algorithm-Based for Time-Cost Optimization. New Developments in Pure and Applied Mathematics. [Electronic resource]. - Access mode: <http://www.inase.org/library/2015/vienna/bypaper/MAPUR/MAPUR-12.pdf>. (Eng)
5. Training materials online. Marketing pricing policy. [Electronic resource]. - Access mode: http://pidruchniki.com/18260617/marketing/vitrati_vklyuchennyam_sobivartist. (Ukr)
6. Yang I.T. Using elitist particle swarm optimization to facilitate bicriterion time-cost trade-off analysis, J. Constr. Eng. Manage. Vol. 133, No. 7, 2007, - pp. 498–505. (Eng)
7. Xiong Y., Kuang Y. Applying an ant colony optimization algorithm-based multiobjective approach for time–cost trade-off, Journal of Construction Engineering and Management, ASCE, Vol. 134, No. 2, 2008, - pp. 153- 156. (Eng)
8. Ng S.T., Zhang Y. Optimizing construction time and cost using ant colony optimization approach, Journal of Construction Engineering and Management, ASCE , Vol. 134, No. 9, 2008, - pp. 721-728. (Eng)
9. Geem Z. W. Multiobjective optimization of time-cost trade-off using harmony search, Journal of Construction Engineering and Management, ASCE, Vol. 136, No. 6, 2010, - pp. 711- 716. (Eng)
10. Leu S., Yang S. Genetic algorithm based multi-criteria optimal model for construction scheduling. Journal of Construction Engineering and Management, 1999, 125(6): 420-427. (Eng)
11. K. El-Rayes and A. Kandil, “Time-cost-quality trade-off analysis for highway construction,” Journal of Construction Engineering and Management, vol. 131, no. 4, pp. 477–486, 2005. (Eng)
12. Zavorotnyi S. M. Factors affecting the time, value and quality of realization to performance based road maintenance contracts / S. M. Zavorotnyi, A. M. Kharchenko // Project management, systems analysis and logistics. - К .: NTU, 2018. - Vol. 1 (Ukr)
13. Zavorotnyi S. M. Optimization of Relations "Time - Cost" to smplement performance based road maintenance contracts / S. M. Zavorotnyi, A. M. Kharchenko // Project management, systems analysis and logistics. Part 1: Series «Engineering» – К.: NTU – 2016. – Vol. 18. (Ukr)
14. Zavorotnyi S. M. Genetic algorithm as optimization method relationship "time - cost" to implement performance based road maintenance contracts / S. M. Zavorotnyi, A. M. Kharchenko // Highways and Road Construction. - К .: NTU, 2018. - Vol. 102. (Ukr)

АЛГОРИТМ ОБГРУНТУВАННЯ ЗАЛЕЖНОСТІ «ЧАС-ВАРТІСТЬ-ЯКІСТЬ» У ДОВГОСТРОКОВИХ КОНТРАКТАХ З УТРИМАННЯ АВТОМОБІЛЬНИХ ДОРІГ

Заворотний Сергій Миколайович, Національний транспортний університет, вул. Омеляновича Павленка 1, Київ, Україна 01010, аспірант кафедри транспортного будівництва та управління майном, e-mail: seregazavorotnyi@gmail.com, тел. +380632406670, <https://orcid.org/0000-0002-2139-8877>

Анотація. В даному дослідженні розглянуто основні групи методів та моделей оптимізації залежності «час-вартість-якість», які умовно можна поділити на: математичні, евристичні та метаевристичні. Наведено основні переваги та недоліки даних методів. Математичні мають високу точність отриманих результатів, але виникає необхідність виконати велику кількість розрахунків. Евристичні більш прості та зрозумілі в порівнянні з іншими, але не забезпечують глобальну оптимізацію. Метаевристичні мають достатній рівень точності розрахунків та досить гнучкі за рахунок поєднання в собі попередніх двох методів.

Також на основі проведеного аналізу було визначено оптимальний метод, який на даний час є найбільш прогресивним. Відповідно до тенденцій розвитку та переваг достатньо ефективним є метаевристичний метод. Для створення алгоритму обґрунтування залежності «час-вартість-якість» було досліджено структуру інноваційної моделі оптимізації часу, вартості та якості проектів будівництва на основі розподілу ресурсів авторів Венфа і Ксінхуа. Детальний аналіз даної моделі дозволив отримати рівняння за допомогою яких можна обґрунтувати залежність «час-вартість-якість».

Ключові слова: довгострокові контракти засновані на кінцевих показниках, експлуатаційне утримання автомобільних доріг, оптимізація.

Перелік посилань

1. Державна цільова економічна програма розвитку автомобільних доріг загального користування державного значення на 2018-2022 роки. [Електронний ресурс]. - Режим доступу: <http://zakon.rada.gov.ua/laws/show/382-2018-%d0%bf>.
 2. Wenfa Hu, Xinhua He. An Innovative Time-Cost-Quality Tradeoff Modeling of Building Construction Project Based on Resource Allocation. Hindawi Publishing Corporation. Scientific World Journal Volume 2014, Article ID 673248, 10 p.
 3. Заворотний С.М. Аналіз методів оптимізації відношення «час – вартість» для реалізації довгострокових контрактів заснованих на кінцевих показниках/ Заворотний С.М., Харченко А.М. //Автомобільні дороги та дорожнє будівництво. – К.: НТУ, 2017. – Вип. 101.
 4. Jorge M-M. Multiobjective Genetic Algorithm-Based for Time-Cost Optimization. New Developments in Pure and Applied Mathematics. [Електронний ресурс]. - Режим доступу: <http://www.inase.org/library/2015/vienna/bypaper/MAPUR/MAPUR-12.pdf>.
 5. Навчальні матеріали онлайн. Маркетингова цінова політика. [Електронний ресурс]. -Режим доступу: http://pidruchniki.com/18260617/marketing/vitrati_vklyuchennyam_sobivartist.
 6. Yang I.T. Using elitist particle swarm optimization to facilitate bicriterion time-cost trade-off analysis, J. Constr. Eng. Manage. Vol. 133, No. 7, 2007, - pp. 498–505.
 7. Xiong Y., Kuang Y. Applying an ant colony optimization algorithm-based multiobjective approach for time–cost trade-off, Journal of Construction Engineering and Management, ASCE, Vol. 134, No. 2, 2008, - pp. 153- 156.
 8. Ng S.T., Zhang Y. Optimizing construction time and cost using ant colony optimization approach, Journal of Construction Engineering and Management, ASCE , Vol. 134, No. 9, 2008, - pp. 721-728.
 9. Geem Z. W. Multiobjective optimization of time-cost trade-off using harmony search, Journal of Construction Engineering and Management, ASCE, Vol. 136, No. 6, 2010, - pp. 711- 716.
 10. Leu S., Yang S. Genetic algorithm based multi-criteria optimal model for construction scheduling. Journal of Construction Engineering and Management, 1999, 125(6): 420-427.
 11. K. El-Rayes and A. Kandil, “Time-cost-quality trade-off analysis for highway construction,” Journal of Construction Engineering and Management, vol. 131, no. 4, pp. 477–486, 2005.
 12. Заворотний С.М. Фактори, які впливають на час, вартість та якість реалізації довгострокових контрактів заснованих на кінцевих показниках / Заворотний С.М., Харченко А.М. //Управління проектами, системний аналіз і логістика. – К.: НТУ, 2018. – Вип. 1.
 13. Заворотний С.М. Оптимізація відношення «час – вартість» для реалізації довгострокових контрактів заснованих на кінцевих показниках/ Заворотний С.М., Харченко А.М. // Управління проектами, системний аналіз і логістика. Ч.1: Серія «Технічні науки» – К.: НТУ, 2016. – Вип. 18.
- Заворотний С.М. Генетичний алгоритм, як метод оптимізації відношення «час – вартість» для реалізації довгострокових контрактів заснованих на кінцевих показниках / Заворотний С.М., Харченко А.М. // Автомобільні дороги і дорожнє будівництво. – К.: НТУ, 2018. – Вип. 102.