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Bubela A.

COMPREHENSIVE ASSESSMENT OF THE QUALITY CONDITION OF THE ROAD WITH DRAINAGE SYSTEM

The object of research is the process of a comprehensive assessment of the qualitative state of a waterlogged section of a road. Natural and climatic factors affect the state of the road due to changes in the conditions of the water-thermal regime and the movement of vehicles. Water, sudden temperature fluctuations, the impact of heavy transport play a key role in the life cycle of any transport structure, affecting its transport and operational characteristics. The definition of a complex indicator of the qualitative state is based on a set of individual indicators, it is comprehensively characterized taking into account the influence of the weightings of each parameter and the structural element of the highway. This is taken into account in the multilevel qualimetric model, which consists of two main groups of physical and functional wear. Indicators of physical wear and tear change over time and are characterized by compliance with certain regulatory indicators and requirements. Functional – do not change over time, but depend on the needs of consumers of transport services. The choice of the number of model levels depends on the weight of the technical and functional characteristics of the road section. Information about the site and its constituent properties increases with the number of levels. Their optimal number determines the volume of measurements and calculations when obtaining a complex indicator of the quality state. The research results made it possible to develop a comprehensive method for assessing the quality state of a waterlogged section of a road where it is necessary to arrange a drainage system. The developed method is based on an expert approach for determining physical and functional indicators, the number of which is determined depending on the parameters of the road. The nomenclature of indicators of the qualitative state of a waterlogged section of the road has been substantiated and a model with an optimal number of indicators has been formed, comprehensively and in full, allows one to characterize all its structural elements in terms of physical and functional wear.

Keywords: *road, water-thermal regime, shallow drainage, qualimetric model.*

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1. Introduction

The road is a complex engineering linear-extended structure that must meet modern requirements for a high-quality transport and operational state. The set of indicators that characterize it makes it possible to determine a complex indicator based on the influence of the weight of each parameter and structural element on the state of the road. This is taken into account in the multilevel qualimetric model of the qualitative state, by determining and adjusting its indicators, which make it possible to determine the physical and functional wear of the road. Their purpose largely determines the validity of the model.

The greatest influence on the state of the road is most often water, which is already in the layers of the road structure, enters through potholes and cracks in the asphalt concrete pavement caused by various factors. Subject to proper drainage from the road structure, which, as a rule, is provided by shallow drainage systems (SDS), the quality condition of the road will meet the standard. The development of a qualimetric model makes it possible to take into account all constructive solutions to maintain the appropriate quality state, is an extremely urgent issue.

2. The object of research and its technological audit

The object of research is the process of a comprehensive assessment of the qualitative state of a waterlogged section of a motor road.

As a toolkit for determining the proper qualitative state of a road, a qualimetric model of a set of indicators that fully characterize it is used. The choice of the number of model levels depends on the importance of the technical and functional characteristics of the road section. With an increase in the number of levels, the information about the site and its constituent properties increases. A multilevel system model, taking into account the large volumes of measurements and calculations, should have an optimal number of levels. Too many levels complicate the assessment process and do not always provide sufficient accuracy.

3. The aim and objectives of research

The aim of research is to develop an integrated method for assessing the quality state of a waterlogged section of a road.

To achieve this aim, it is necessary to complete the following objectives:

1. On the basis of the parameters characterizing the physical and functional wear and tear of a road section with a drainage system, determine the weighting coefficients of the indicators of the qualitative state by the expert method.

2. To develop a qualimetric and mathematical model for assessing the quality state of a waterlogged road section.

4. Research of existing solutions of the problem

In works [1, 2], the assessment and determination of indicators of the qualitative state of the road is carried out using a generalized approach that does not take into account the specifics of the operation of a waterlogged area. As indicated in [3], a comprehensive assessment of highways is a laborious process that requires the involvement of specialists. Extensive field observations by experts are carried out to characterize the pavement condition index based on established physical parameters such as cracking, deformation, sliding. In addition, improper drainage contributes to unstable road conditions identified by experts during road surveys and which can lead to natural disasters [4]. Therefore, there is a certain need to use transport modeling for the development of design solutions, by building models necessary to solve various problems of the transport and operational state of the highway [5]. In works [6, 7], it is proposed to use qualimetry to determine the level of a qualitative state. However, the difficulties of using this method are the specific features and the richness of the parameters of highways. Fundamentally new methodological approaches to determining the weights of characteristics and parameters of objects of assessment are given in [8, 9]. However, these methodological approaches can be used in this study only partially and only for the construction of a methodology for determining the weights of the parameters of a road section.

Qualimetry principles have been applied by many researchers in various fields to interpret qualitative parameters. For the mathematical formalization of information about the level of the qualitative state of road infrastructure objects is emphasized in [10]. However, most of the analyzed mathematical models in the above studies do not allow determining the influence of the parameters and characteristics of a road section on its level of qualitative state. The issues of taking into account the actual level of the quality state and the reliability of information about physical and functional wear and tear remain unresolved. This makes it promising for the development of a mathematical model for assessing the quality state of a waterlogged road section.

5. Methods of research

The presented method is based on the methods developed by the authors [1, 2, 11].

In the qualimetric model for assessing the qualitative state of a road section, the indicators are divided into two main groups: physical wear and tear and functional indicators. Physical wear and tear change over time and it can be characterized by a numerical value or certain standard indicators governing compliance or non-compliance with the requirements for the proper functioning of a road section. Functional indicators do not change over time, but their compliance depends on the consumers of transport services [12].

As a result of the division of complex and medium properties into simple ones, the number of levels increases. The model is considered complete, complete when the last p-th level is represented by simple, indivisible properties. This approach makes it possible to form various variants of state indicators.

The properties of each level have a mutual influence on each other, and the generalized properties of one level affect the generalized properties of another. A complex property at the lowest zero level is characterized by a set of properties located at higher levels and is a separate complex indicator (Fig. 1).

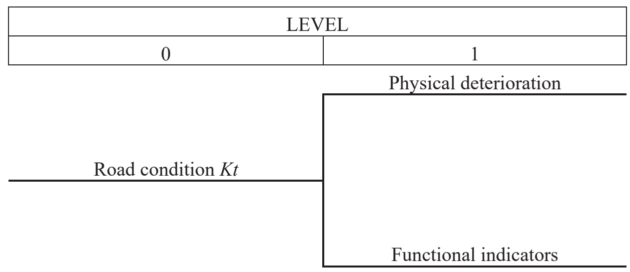

Fig. 1. Zero and first levels of the qualimetric model of a road section

So, there is a certain quantitative relationship between the complex indicator of the state of the road section and the i-th property of the p-th level.

At any level (Fig. 2), each property is characterized not only by a differential indicator, but also by a weight coefficient, reflecting the value of the significance of a differential indicator in a complex indicator. Mathematically, the process of constructing a qualimetric model of the state of a road section can be represented by the formula:

$$K_t = f(K_{i1}, K_{i2}, \ldots K_{ij}), \quad (1)$$

where K_t – the state level, in the form of a coefficient $K_t \in [0;1,0]$, $\{K_t \in Q\}$; K_{ij} – the value of the j-th indicator at the i-th level of the model; i – the level of the model, $\{i \in P\}$; j – the number of indicators within the i-th level of the model, $\{j \in L\}$; Q, P, L – the set of rational numbers.

The level of the qualitative state of the road section is a value dependent on the aggregate of indicators of the highest subgroup, taking into account their significance, according to the qualimetric model [13–16]:

$$K_t = \sum_{j=1}^{l} K_{lj} \cdot m'_{lj}, \quad (2)$$

where m'_{lj} – the weight coefficient of complex (complex) properties that characterize the state of the road section at the first (highest) level of the model; l – the number of groups of indicators, $\{l \in N\}$.

Accordingly, at the low level of the model:

$$K_{pj} = \sum_{j=1}^{l'} P_{pj} \cdot m_{pj}, \quad (3)$$

where P_{pj} – single differential indicator of the state of the motor road at the level p of the model; m_{pj} – coefficient of weighting of simple properties characterizing the state

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of the road at the low level of the model (p); l' – the number of indicators (properties) of the considered road element at the level p of the model, $\{p \in N\}$.

Each level of properties of a highway can be quantitatively determined by a single (differentiated) indicator of the state:

$$P_{pj} = \frac{P_{pj}^a}{P_{pj}^b} \text{ or } P_{pj} = \frac{P_{pj}^b}{P_{pj}^a}, \quad (4)$$

where P_{pj}^a – value of the j-th absolute indicator of the state at the low level of the model (p); P_{pj}^b – value of the j-th base (reference) indicator of the state at the low level of the model (p).

At the same time, a single indicator is a dimensionless value that determines the level of the road condition in the form of a coefficient or as a percentage. However, the process of obtaining the K_{pi} indicator in the model is complicated by the fact that it is necessary to clearly define the significance of each indicator in the hierarchical system.

The weight of properties at any level or in a group of a given level is subject to the dependence:

$$\sum_{i=1}^{n} m_i = k = \text{const}, \quad (5)$$

where k – constant value equal to one for fractional values m_i and equal to 100 when presented m_i as a percentage.

In each group $\sum m'_j = 1$ at each level $\sum m_i = 1$, in addition $m_i < m'_j$. According to the results of calculations, each relationship of the model is characterized by four indicators – the number, the name of the indicator of the qualitative state, the group weighting factor m'_j and the level factor.

The values of the weighting factors can be determined by the following methods: cost, expert, statistical and combined [12]. The use of the first two provides for the determination of the relationship between the single indicators with the involvement of experts. But the main disadvantage of this group of methods is the subjective approach. The essence of the cost method lies in a simplified approach to determining the indicators of weight, that is, according to a consolidated estimate of the cost of building a section of a highway in accordance with modern prices. But it should be noted that the cost is a non-constant value that depends on many factors, therefore, with insignificant fluctuations in it, the reliability of the obtained weight values can significantly decrease.

The cost method is based on the assumption that quality is proportional to cost, and weight is identical to cost:

$$m_{ij} = f\left(C_j\right) \rightarrow m_{ij} = \frac{C_j}{\sum_{j}^{l'} C_j}, \quad (6)$$

where m_{ij} – the weighting coefficient of the j-th property at the i-th level; C_j – the estimated cost of the j-th characteristic (motor road, component or structural element of a road section); $\sum_j^{l'} C_j$ – the total estimated cost of the road section, component or element; l' – the number of indicators (properties) of the considered road section, component or element at the i-th level of the model.

The expert method for determining the weighting factors is based on the analysis of the opinions of specialists who assess the quality of the elements of the object of assessment. In relation to the average assessment of experts to the total sum of average assessments, group weighting factors are determined for each property of the object. The weight coefficient of the i-th property of this group is determined by the formula:

$$m'_i = \frac{\frac{1}{n}\sum_{i=1}^{n} N_{ij}}{\frac{1}{k}\sum_{j=1}^{k}\sum_{i=1}^{n} N_{ij}}, \quad (7)$$

where N_{ij} – the i-th property in points, assessed by the j-th expert; k – the number of properties in the group; n – the number of experts.

For each group, the condition is satisfied, described by formula (5). After a similar determination of the weighting factors of the indicator for each group, the weighting factors of each property are calculated for the level.

The determination of the weight coefficients of some characteristics of the road can be carried out in two ways: determine the arithmetic mean or use mathematical weighting. The best way to subjectively weigh the end results is to determine the weighting factors using the formula:

$$m_{ij} = \sum_{j=1}^{q} m_j \cdot z_j, \quad (8)$$

where m_{ij} – the weighting coefficient of simple properties characterizing the state, determined by the j-th method; j – the number of applied method $\{j \in N\}$; q – the number of applied methods; Z_j – specific coefficient of the j-th method.

In the absence of data on some indicators, the weighting factors of the remaining calculated indicators are increased as follows:

$$m_{ijn} = m_{ij} + \frac{\sum_{i=1}^{q} m'_{ij}}{n-q}, \quad (9)$$

where m_{ijn} – new value of the weighting coefficient; q – the number of missing factors with weighting factors.

Natural and climatic factors affect the state of the road due to changes in the conditions of the water-thermal regime and the movement of vehicles. The greatest destructive effect on all structures, structures and elements of the road is exerted by water, sudden temperature fluctuations, and the impact of heavy transport.

Water plays a key role in the life cycle of any transport structure, affecting its transport and operational characteristics. It is known that the absence of excess moisture in road structures and subgrade soils means its proper functioning. Excessive moisture content reduces the bearing capacity, promotes the development of deformation of the pavement, which leads to accelerated destruction and a reduction in the service life of the road. In such cases, more frequent repairs are required on sections of the road with drainage problems. When determining the type of repair work, the costs of installing the coating must be compared with the costs of maintaining the drainage system in proper condition.

In order to ensure the high-quality condition of the road section with operating costs minimized, it is necessary to design the structural layers so that they can be quickly drained in a short period of time. For the working area of the road structure, this function is performed by SDSs, which are arranged from various materials in terms of physical and chemical properties that affect the intensity of drainage.

The existing methods for determining the weights of the parameters of shallow drainage systems in the road structure are of a scattered nature and, first of all, are aimed at ensuring sufficient culverts.

6. Research results

The initial data for determining the main indicators of the group of physical wear and tear, in accordance with the constituent structural elements of the road, are building codes [17]. The second group (functional wear) includes such indicators that are usually laid down at the design stage of a road section [2]. The main indicators of physical and functional wear, affecting the quality condition of the road section are the indicators of the 2nd level of the model. Each of these indicators is characterized by simpler (differential) indicators – levels 3 and 4 (Fig. 2, 3).

The physical deterioration of the road section is characterized by 8 indicators (K1–K8), where the third of them, in turn, is also subdivided into groups from 3 to 5 indicators (level 3, Fig. 2). If the drainage layer works according to the absorption principle, then SDSs are not satisfied, their significance is equal to 0 and, accordingly, the value of other indicators is listed according to (9). If the drainage layer works on the principle of drainage, then either transverse SDS, or longitudinal SDS, or complex SDS are suitable. In turn, functional wear is characterized by 4 indicators (K9–K12), where the second of them is divided into groups according to 6 indicators (level 3, Fig. 3).

The values of indicators of the 2nd level of physical wear K1–K8 in Fig. 2 are determined using the value method. In addition, there are indicators that can't be estimated using the cost method, therefore the weighting factors in Fig. 2, 3 are determined on the basis of a combination of two methods of expert and cost [1, 2]. The initial data for their determination are the results of field studies, estimate documentation, departmental regulatory framework, as well as data obtained by questioning experts in the road industry (Table 1) and can be changed depending on hydrological and soil-geological conditions.

According to the approaches of the expert method, which are considered in detail when constructing the qualimetric model in [1, 2], the indicators of physical wear of the 3rd and 4th levels re determined (Fig. 2). And also all indicators of functional wear of the 2nd and 3rd levels (Fig. 3).

Upon detailed examination, the indicator «drainage system» in the group of physical wear and tear is divided into 4 simple indicators that have their effect on the quality of the road. In turn, such a structural element as a transverse SDS is characterized by 5 indicators. Thus, the priority of the factors that determine the technical and technological indicators of the SDS and the corresponding weight factors is determined at level 4 (Fig. 2).

As for the functional indicators of the qualitative state, their influence on the complex indicator is 26 %. But there is a definite connection between physical and functional wear and tear. That is, if to consider the efficiency of the drainage system, then the functional indicator of the qualitative state depends on 4 indicators of the 3rd level of the model, namely, the longitudinal and transverse slopes of the road section, the slope of the drainage trench and drainage of surface runoff located in different groups (Fig. 3).

Substantiation of the weighting coefficients of the qualitative state indicators of the structural elements of the highway on the basis of expert assessments is presented in Table 1.

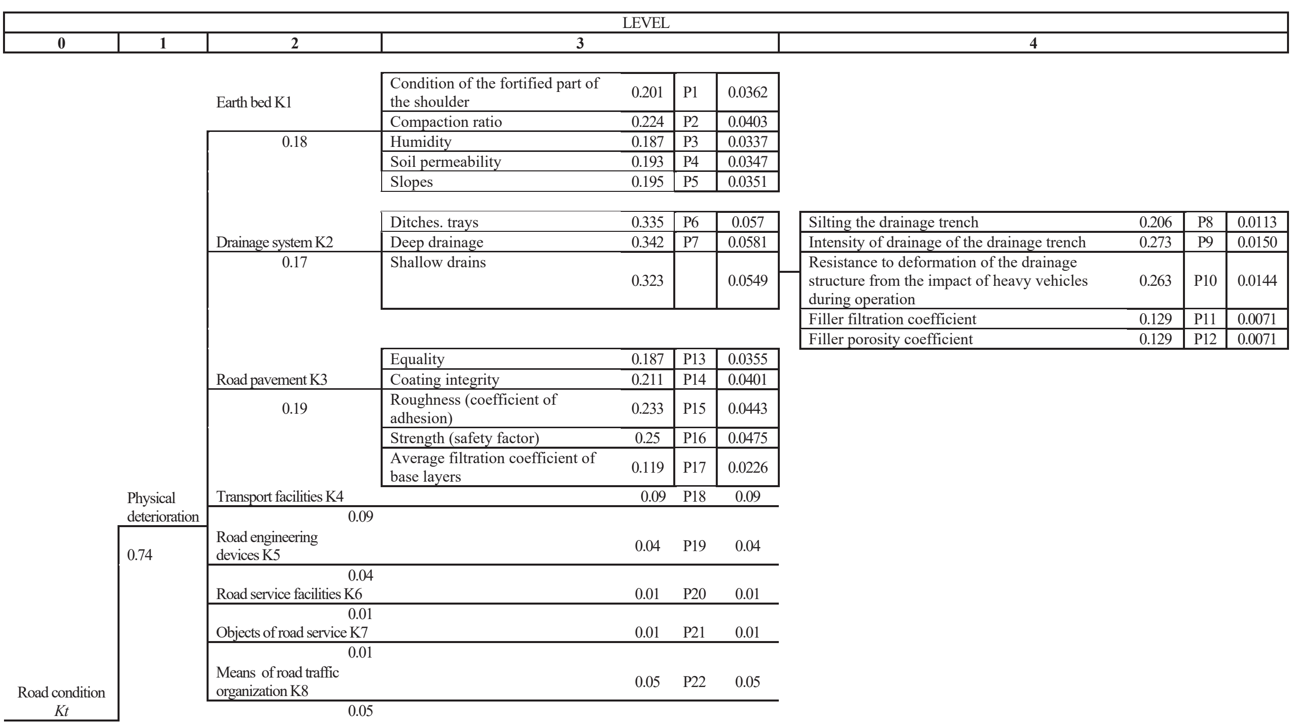

Fig. 2. Indicators of physical wear and tear of road sections with excessive moisture

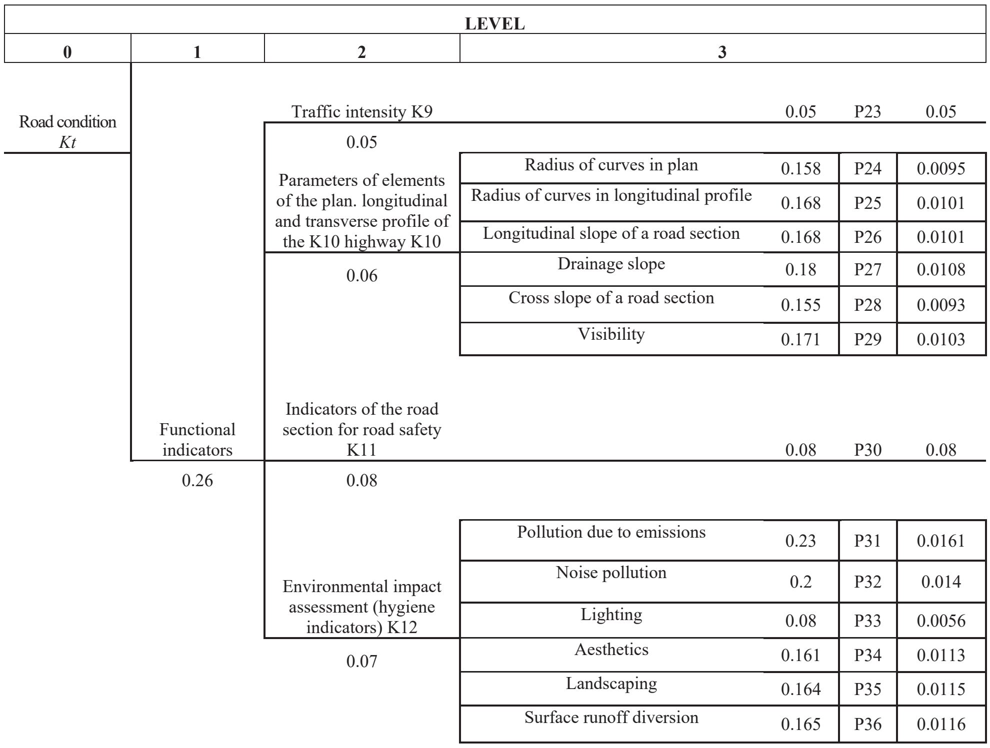

Fig. 3. Functional indicators of the state of the road, taking into account their weight

Table 1

Determination of the weighting factors of the indicators of the qualitative state of the structural elements of the highway using the expert method

No.	Expert estimates					Average rating	Sum of average estimates	Group property weighting factor	Indicator weighting factor	Leveled property weighting factor	Structural element
	1	2	3	4	5						
1	2	3	4	5	6	7	8	9	10	11	12
1	59	62	63	57	64	61	304	0.201	0.18	0.0362	condition of the fortified part of the shoulder
2	65	69	71	67	68	68		0.224		0.0403	compaction ratio
3	60	57	56	53	59	57		0.187		0.0337	humidity
4	56	62	58	54	65	59		0.193		0.0347	soil permeability
5	61	60	57	59	58	59		0.195		0.0351	slopes
6	97	95	94	98	96	96	287	0.335	0.17	0.0570	ditches, ditches. trays
7	97	99	98	97	99	98		0.342		0.0581	deep drainage
	93	90	96	94	92	93		0.323		0.0549	shallow drains
8	76	74	72	73	75	74	358	0.206	0.0549	0.0113	silting the drainage trench
9	97	99	98	97	99	98		0.273		0.0150	intensity of drainage of the drainage trench
10	95	96	92	94	93	94		0.263		0.0144	resistance to deformation of the drainage structure from the impact of heavy vehicles
11	43	48	45	46	48	46		0.129		0.0071	filtration coefficient of filler
12	48	47	42	49	44	46		0.129		0.0071	filler porosity coefficient
13	60	63	57	59	61	60	321	0.187	0.19	0.0355	equality
14	62	69	71	68	70	68		0.211		0.0401	coating integrity
15	75	78	73	74	75	75		0.233		0.0443	roughness (coefficient of adhesion)
16	79	83	78	81	79	80		0.25		0.0475	strength (safety factor)
17	42	38	34	37	39	38		0.119		0.0226	average filtration coefficient of base layers
18	n/d	n/d	n/d	n/d	n/d	26	26	1	0.09	0.0900	transport facilities
19	n/d	n/d	n/d	n/d	n/d	30	30	1	0.04	0.0400	road engineering devices
20	n/d	n/d	n/d	n/d	n/d	32	32	1	0.01	0.0100	road service facilities

Continuation of Table 1

1	2	3	4	5	6	7	8	9	10	11	12
21	n/d	n/d	n/d	n/d	n/d	31	31	1	0.01	0.0100	road service facilities
22	n/d	n/d	n/d	n/d	n/d	24	24	1	0.05	0.0500	traffic management equipment
23	27	26	28	24	25	26	26	1	0.05	0.0500	traffic intensity
24	18	17	15	14	16	16	101	0.158	0.06	0.0095	radius of curves in plan
25	17	16	17	18	17	17		0.168		0.0101	radius of curves in longitudinal profile
26	19	15	16	17	18	17		0.168		0.0101	longitudinal slope of a road section
27	20	16	18	19	17	18		0.18		0.0108	drainage slope
28	15	16	16	18	15	16		0.155		0.0093	cross slope of a road section
29	21	17	19	20	18	17		0.171		0.0103	visibility
30	30	29	33	32	31	31	31	1	0.08	0.0800	indicators of the road section for road safety
31	25	29	26	28	27	27	118	0.23	0.07	0.0161	pollution due to emissions
32	25	24	26	20	25	24		0.2		0.0140	noise pollution
33	8	9	10	11	7	9		0.08		0.0056	lighting
34	21	17	19	20	18	19		0.161		0.0113	aesthetics
35	20	19	19	17	20	19		0.164		0.0115	landscaping
36	21	20	19	20	20	20		0.165		0.0116	wastewater disposal

Note: n/d – not determined by the expert method

The group weighting coefficient of the property is determined by the formula (7). The weighting factor of the indicator was determined by the cost method. The level weighting factor of a property is the product of the group weighting factor of a property and the weighting factor of an indicator.

Taking into account such a number of qualitative signs of the state of the road, a mathematical model of the qualitative state of a section of the road has been developed, which makes it possible to bring all properties to a single indicator of the model, that is, to transform all simple properties on a single scale:

$$\begin{aligned} K_t &= 0.0362\cdot P_1 + 0.0403\cdot P_2 + 0.0337\cdot P_3 + \\ &+ 0.0347\cdot P_4 + 0.351\cdot P_5 + 0.0570\cdot P_6 + \\ &+ 0.0581\cdot P_7 + 0.0113\cdot P_8 + 0.0150\cdot P_9 + \\ &+ 0.0144\cdot P_{10} + 0.0071\cdot (P_{11} + P_{12}) + 0.0355\cdot P_{13} + \\ &+ 0.0401\cdot P_{14} + 0.0443\cdot P_{15} + 0.0475\cdot P_{16} + \\ &+ 0.0226\cdot P_{17} + 0.09\cdot P_{18} + 0.04\cdot P_{19} + 0.01\cdot P_{20} + \\ &+ 0.01\cdot P_{21} + 0.05\cdot P_{22} + 0.05\cdot P_{23} + 0.0095\cdot P_{24} + \\ &+ 0.0101\cdot P_{25} + 0.0101\cdot P_{26} + 0.0108\cdot P_{27} + 0.0093\cdot P_{28} + \\ &+ 0.0103\cdot P_{29} + 0.08\cdot P_{30} + 0.0161\cdot P_{31} + 0.014\cdot P_{32} + \\ &+ 0.0056\cdot P_{33} + 0.0113\cdot P_{34} + 0.0115\cdot P_{35} + 0.0116\cdot P_{36}. \quad (10) \end{aligned}$$

The advantage of this model is that it makes it possible to determine a complex indicator that takes into account the influence of each differential indicator both on a certain level of the model and on certain groups and types of indicators. The peculiarity of this mathematical model is that it takes into account physical and functional wear not only as a calculated value according to the standards, but also as a result of determining the state of the waterlogged section of the road using the basic provisions of qualimetry.

7. SWOT analysis of research results

Strengths. In comparison with analogs, the developed method is based on an expert approach to determine the weights of physical and functional indicators, the number of which depends on the characteristics of the road section. This method makes it possible to evaluate indicators that cannot be analyzed by another method and, accordingly, to obtain a generalized assessment of the qualitative state of the road section.

Weaknesses. The expert method is based on the professional level of experts and on the subjective decision of each of them.

Opportunities. It can be used for any transport structure, taking into account the state of its structural elements.

Threats. It requires constant adjustment of the coefficients of weighting of the indicators of the qualitative state, taking into account the degree of physical wear and tear of the transport structure and the parameter of functional wear, which depends on many external factors.

8. Conclusions

1. The proposed model takes into account the specific features and characteristics of indicators of the qualitative state of the road, and is also based on an integrated approach to a rational combination of methods for determining and substantiating their weightings. The determination of the weighting factors for each indicator and elements of the road, taking into account the drainage system, is carried out by the method of arithmetic mean or mathematical weighting.

2. A qualimetric model has been developed on the basis of a multilevel hierarchical system of indicators of the qualitative state of a road section with excessive moisture, which is characterized by 12 indicators of the 2nd level. Of these, 5 have components of the 3rd level (25 indicators), and also, taking into account the peculiarities of

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the operation of the road section in the zone of excessive moisture, are specified by the indicators of the 4th level. A mathematical model of the qualitative state has been obtained, which takes into account the design and construction parameters of the road section, including shallow drainages. The model makes it possible to characterize in a generalized way a complex indicator of the qualitative state of a road section, which is the initial parameter for determining the costs of its operational maintenance.

References

1. Slavinska, O., Savenko, V., Kharchenko, A., Bubela, A. (2017). Development of a mathematical model of eevaluation of road-and-transport assets as a component of information-and-management system. *Eastern-European Journal of Enterprise Technologies, 6 (4 (90)),* 45–57. doi: http://doi.org/10.15587/1729-4061.2017.118798
2. Slavinska, O., Stozhka, V., Kharchenko, A., Bubela, A., Kvatadze, A. (2019). Development of a model of the weight of motor roads parameters as part of the information and management system of monetary evaluation. *Eastern-European Journal of Enterprise Technologies, 1 (3 (97)),* 46–59. doi: http://doi.org/10.15587/1729-4061.2019.156519
3. Herold, M., Dar, R., Smadi, O., Noronha, V. (2004). *Road condition mapping with hyperspectral remote sensing.* Available at: https://www.researchgate.net/publication/228608996_Road_condition_mapping_with_hyperspectral_remote_sensing
4. Puri, E. R. (2017). Development of Parameters of Road Conditions based on Road User/Citizen Satisfaction. *IPTEK Journal of Proceedings Series, 3 (5).* doi: http://doi.org/10.12962/j23546026.y2017i5.3174
5. Solodkiy, A., Gorev, A. (2018). Determination of basic factors for the successful implementation of the safe and high-quality roads project. *Transportation Research Procedia, 36,* 741–746. doi: http://doi.org/10.1016/j.trpro.2018.12.097
6. Leonova, T. I., Kalazhokova, Iu. A. (2015). Kvalimetricheskaia model otsenki kachestva nauchno-tekhnicheskikh rabot. *Fundamentalnye issledovaniia, 6-1,* 143–147. Available at: http://www.fundamental-research.ru/ru/article/view?id=38410
7. Barinov, N. P., Abbasov, M. E. (2016). *O korrektnom ispolzovanii kvalimetricheskikh protsedur pri otsenke nedvizhimosti.* Biblioteka LABRATE.RU. Available at: http://www.labrate.ru/articles/2016-barinov-abbasov.pdf
8. Oleinikov, B. V., Beskorsii, N. S. (2014). O vliianii shkaly na rezultaty mnogokriterialnogo vybora v metodologii AHP T. Saati. *Obrazovatelnye resursy i tekhnologi, 1 (4),* 331–337. Available at: https://www.muiv.ru/vestnik/pdf/pp/ot_2014_1_331-337.pdf
9. Tikhomirova, A. N., Sidorenko, E. V. (2012). Modifikatsiia metoda analiza ierarkhii T. Saati dlia rascheta vesov kriteriev pri otsenke innovatsionnykh proektov. *Sovremennye problemy nauki i obrazovaniia, 2.* Available at: http://www.science-education.ru/ru/article/view?id=6009
10. Lapidus, A., Makarov, A. (2016). Fuzzy sets on step of planning of experiment for organization and management of construction processes. *MATEC Web of Conferences, 86,* 05003. doi: http://doi.org/10.1051/matecconf/20168605003
11. *MR D 1.2-37641918-884:2017. Metodychni rekomendatsii z provedennia vartisnoi otsinky avtomobilnykh dorih i sporud na nykh* (2017). Kyiv, 92.
12. Sidenko, V. M., Rokas, S. Iu. (1981). *Upravlenie kachestvom v dorozhnom stroitelstve.* Moscow: Transport, 252.
13. Slavinska, O. S. (2016). Application of transformation assessment tasks highways managment methodology of property evalution road on the basis of transformation. *Roads and road construction, 96,* 104–111.
14. Bubela, A. V. (2016). Project management of estimates of the roads based on considerstion of the technical state. *Roads and road construction, 97,* 50–55.
15. Slavinska, O. S. (2016). Metodolohiia mainovoi otsinky avtomobilnoi dorohy, yak obiekta derzhavnoi vlasnosti. *Avtomobilni dorohy i dorozhnie budivnytstvo, 97,* 70–77.
16. Bubela, A. V. (2016). Vykorystannia dyferentsiinoho metodu v proektakh budivnytstva avtomobilnoi dorohy dlia obliku ta otsinky aktyviv dorozhnoho hospodarstva. *Avtomobilni dorohy i dorozhnie budivnytstvo, 98,* 22–29.
17. *DBN V.2.3-4:2015. Avtomobilni dorohy. Proektuvannia. Budivnytstvo. Vved. 2016-04-01* (2015). Kyiv: DP «Ukrarkhbudinform», 104.

Bubela Andrii, *PhD, Associate Professor, Department of Transport Construction and Property Management, National Transport University, Kyiv, Ukraine, e-mail: bubelaandrey@ukr.net, ORCID: http://orcid.org/0000-0002-5619-003X*