Розглянуто проблеми вартісної оцінки активів в системі управління дорожньо-транспортною інфраструктурою. Пропонується використання кваліметричної моделі як основи вартісної оцінки активів дорожньо-транспортного комплексу з урахуванням фізичних та функціональних особливостей. Розроблено математичну модель вартісної оцінки активів дорожньо-транспортного комплексу, яка відповідає сучасним вимогам, з можливістю реалізації в інформаційно-управлінській системі

Ключові слова: вартість активів, вартісна оцінка, інформаційно-управлінська система, рівень якісного стану, кваліметрія

Рассмотрены проблемы стоимостной оценки активов в системе управления дорожно-транспортной инфраструктурой. Предлагается использование квалиметрической модели как основы стоимостной оценки активов дорожно-транспортного комплекса с учетом физических и функциональных особенностей. Разработана математическая модель стоимостной оценки активов дорожно-транспортного комплекса, отвечающая современным требованиям, с возможностью реализации в информационно-управленческой системе

Ключевые слова: стоимость активов, стоимостная оценка, информационно-управленческая система, уровень качественного состояния, квалиметрия

DEVELOPMENT OF A MATHEMATICAL MODEL OF EEVALUATION OF ROAD-AND-TRANSPORT ASSETS AS A COMPONENT OF INFORMATION-AND-MANAGEMENT SYSTEM

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1. Introduction

One of the most important lines of social and economic development of Ukraine is optimization of the motorway network and substantial improvement of the operational condition of motorways as the factor of economic effectiveness of the entire transportation process in the country. This can be achieved by successful implementation of the national concept of the target economic program of development of motorways in 2013–2018. The program is aimed at a significant improvement of the economic effectiveness of trucking and passenger transportation, road safety improvement, rise of mobility, saving fuels and lubricants and bettering vehicle service.

To implement this program, it is necessary to adopt concession construction of roads and invite private companies for their participation in the national programs of improvement of the country's infrastructure in a short term.

Stocktaking, systematization of information on the qualitative state and fair evaluation of existing assets of the road sector, adequate updating of databases are the prerequisites for improving effectiveness of managerial decisions on the road infrastructure facilities [1].

In order to further improve and develop scientific studies in the field of national road-and-transport management, it is necessary to develop a real tool for conducting technical expert appraisal and evaluation of motorways. The results of road evaluation are necessary for making managerial decisions by executive authorities, local self-government bodies and organizations of the road sector. Monitoring how the asset value changes in time can provide convincing arguments in favor of investing in upgrading and building of the motorway network. The experience gained by other countries (e. g., Finland, New Zealand, Australia, the USA, Canada) has shown that substantiation of the value of infrastructure facilities substantially influences management of the road network. It was proved that the road evaluation affects the level of operation and maintenance and repair financing which, in general, results in improvement of the state of the road-and-transport infrastructure facilities.

Countries such as the United Kingdom, the United States, Australia, Germany, Canada, Finland, and New Zealand have developed guidelines for valuating roads as assets taking into account international standards of evaluation (ISV) [2] and the specifics of their own legislation. It should be noted that current evaluation standards were

developed and applied for liquid assets. They cannot be used for a specialized illiquid property of the road-and-transport infrastructure (roads and their elements).

National guidelines for evaluating the road property are still at the testing stage in the countries of their elaboration.

In connection with attraction of private capital, in particular into the transport sector, there is a real need for an expert appraisal of transport facilities. The specifics of the road sector property require a special approach to its monetary expert evaluation. At the present stage, there are no concrete legal normative documents that would take into account this specificity when carrying out evaluation. Therefore, development of a mathematical model of evaluation of road-and-transport assets is a topical issue.

2. Literature review and problem statement

There are a number of problems associated with application of existing methods for valuating road assets. The first limitation is that the existing methods consider these assets as a monolithic structure and thus assume that the level of its qualitative state corresponds to the level of qualitative state of the asset elements. However, far from being monolithic, any road asset actually has a wide range of elements and indicators that can differ significantly by diverse parameters of physical and/or functional depreciation. It is proposed in works [3, 4] to solve this problem in a conventional way, i. e. by the method of aggregated indicators of the renewable value. However, it should be noted that the traditional mathematical models implicitly consider physical and functional depreciation of the road assets or only take into account duration of their life cycle which can significantly distort the assessed value.

It is proposed in works [1, 5–7] to consider road assets in accordance with the multistructural approach and take into account physical and functional depreciation as a level factor of the qualitative state. However, the question remains open regarding determination of the qualitative state level for each element and its impact on the aggregate qualitative state of the road asset. In papers [8, 9], it is proposed to determine the quality level of the assets of road-and-transport infrastructure by a qualimetric model. Such an approach was proposed as a basic one in work [10] with comprehension of the problem of measurement and assessment of quality in conjunction with the problem of qualitative management of products and works in public production. However, this approach concerns just civil and industrial construction.

Present-day studies are based on assessment of the quality level by a dimensionless scale [11] with the use of the information-process model [12]. Such an approach to assessing the quality level fundamentally differs from the conventional one. Since qualities of the studied object are not considered separately, a single generalized indicator characterizing the joint effect of each quality on the object is determined. The advantages of applying the fundamental principles of qualimetry to interpretation of qualitative parameters of the production environment are proved by many studies in various fields [8–10]. Importance of mathematical formalization of information on the level of the qualitative state of facilities of the road-and-transport complex is emphasized in [13]. However, most of the analyzed mathematical models in the above studies do not allow one to determine effect of the qualitative state level on the value of the object under consideration.

The issues of taking into account the actual level of quality and reliability of information on physical and/or functional depreciation of the asset remain unresolved. Conventional mathematical models of valuating immovable facilities take into account physical depreciation rather roughly and only for the facilities of civil and industrial construction while the level of qualitative state is not considered at all.

This shows that the line of constructing mathematical models for evaluation of the road-and-transport infrastructure assets taking into account the level of quality state is promising.

3. The aim and objectives of the study

This study objective was to develop a mathematical model for valuating road-and-transport infrastructure assets taking into account their level of qualitative state as a component of the information-and-management system.

To achieve this objective, the following tasks had to be solved:

– define the process of asset evaluation as an element of management of the road-and-transport complex;

– construct a conceptual model of the evaluation procedure taking into account problems of consideration of the qualitative state level;

– develop a set of models for estimating the level of qualitative state of facilities and valuating the road-and-transport complex assets.

4. Materials and methods of evaluation of assets as a component of the information-and-management system

4. 1. Studying the process of evaluation of assets as an element of management of the road-and-transport complex

Evaluation of assets is the key element of asset management and is regarded as a component of the information and management system of the road sector (Fig. 1) [6, 7].

Information-and-analysis systems have been successfully introduced and used in the road sector. The main of these are: Road Pavement Control System (RPCS), Analytical Expert System of Bridge Management (AESBM), Electronic Road Passport (ERP), Road Traffic Organization Project (RTOP), The Sector Database of Traffic Accident Registration, The Unified Database of Operation Condition of State Roads and Their Engineering Structures (BOC) system is used since 2007.

Besides, a new software complex was created: The Road Routine Repair and Maintenance Control System (RRRMCS). The RRRMCS software complex is a set of models and methods, databases and software in the system of road state management. The purpose of this software complex is substantiation of making managerial decisions concerning the level of road maintenance under existing restraints.

In 2012, on the basis of web technologies, information-and-analytical system of Ukrainian Road Sector Management (IAS RSM) [14, 15] was developed. However, one of the main problems of the existing road-and-transport management system is the fact that for each asset, the information on its book value is used and not on a fairly determined value. To solve this issue, a scheme of evaluation of the road-and-transport infrastructure assets is proposed (Fig. 2).
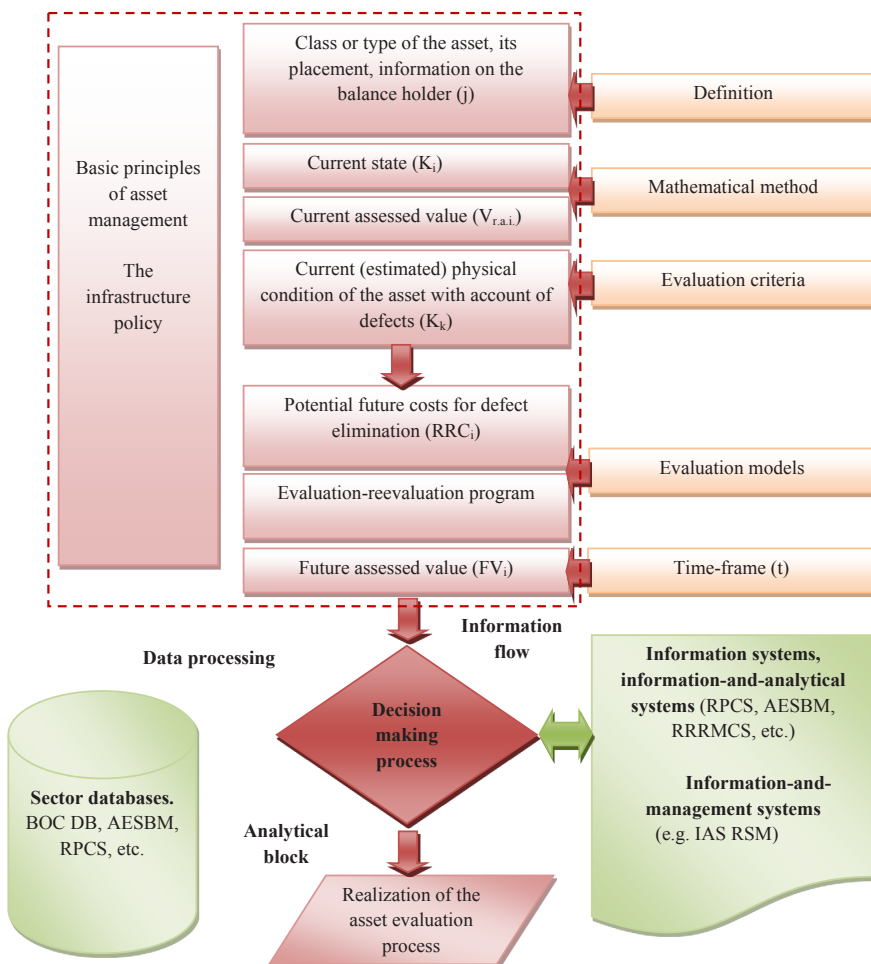
Evaluation of the motorway and its structures is the process of evaluation of transport facilities on the date of evaluation in accordance with the procedure established by the normative and legal acts of property evaluation [16–18].

Evaluation of assets requires information about [6, 7]:

a) management structure;

b) policy of accounting and methodology of the actual asset evaluation;

c) indicators of effectiveness and functions of depreciation or a depreciation model for valuating future assets;

d) information systems on the state of the road net and the value of assets.

Evaluation is important for providing appropriate managerial information to optimize the total value of the life cycle of the national road net. Road assets are valuated to determine real current value of the assets, forecasting the cost of repair and restoration works [16–18] and inventory [19–21].

4. 2. Construction of the conceptual model of the evaluation procedure taking into account the problems of taking into account the level of qualitative state

The value of assets can be expressed as follows:

a) as an effective transportation of people and goods, i.e. as an internal economic value for the transport net as a whole;

b) as the cost of capital or the assessed value taking into account the historical value and the cost of renewal or the cost of asset substitution.

Evaluation of assets is carried out to determine physical state of the asset in monetary terms [22].

In the classical sense of asset evaluation, in accordance with the national standards of Ukraine, rather than proceeding to the evaluation process itself, a conceptual model of the procedure which, for road assets, is based on a cost approach must be constructed. Namely, it is necessary to conduct studies of structures, the road land plots and other infrastructure facilities and the legal order of maintenance of land plots. The next step is estimating the value of structures, transport facilities and land plots.
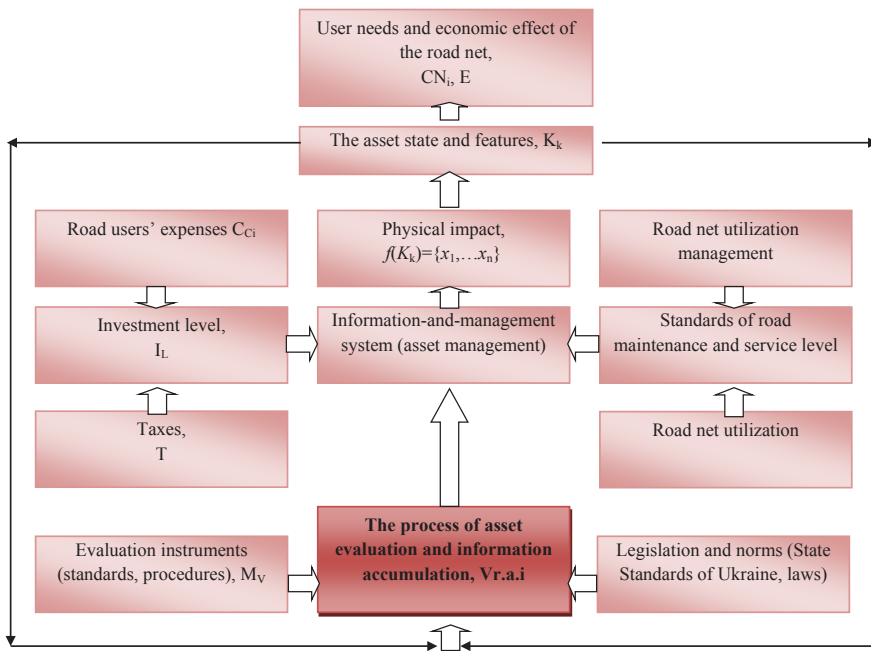

Fig. 1. Information-and-management system
(road-and-transport infrastructure asset management system)

Fig. 2. The scheme of the process of evaluation of
the road-and-transport complex assets

The assessed value of a road asset can be formalized according to the multi-structural approach [23–25] as follows:

$$V_{r.a.i} = f_{mi}\left(\sum_{j=1}^{j=mi} V_{r.a.e.j} + V_l\right); \ \{j \in U\}; \ \{i \in N\}, \tag{1}$$

where $V_{r.a.i}$ is the assessed value of the i-th road asset, mon. un.; $V_{r.a.e.j}$ is the assessed value of the j-th element of the road asset determined by the cost approach, mon. un.; V_l is the value of the land plot determined in accordance with the current legislation on evaluation of land plots, mon. un.; f_{mi} is the function of calculation of the road asset value taking into account the net effect of its elements on the value; U is the aggregate of homogeneous elements of the road asset.

Classical methods based on the cost approach include [5, 6, 27, 28]:

a) the method of asset reevaluation/additional evaluation;

b) the method of boundary state;

c) the method of fixed cost with respect to the boundary state;

d) the method of the transferred value (substitution).

For application of these methods taking into account the determined level of qualitative state according to [8], it is necessary to modify the conventional approach consisting in arrangement of the base value by deduction of physical and/or functional depreciation.

$$V_{r.a.e.} = V_b - D, \tag{2}$$

where V_b is the base value of the road asset element, mon. un; D is depreciation (physical and/or functional) of the road asset element, mon. un.

The main problem in evaluation of property by conventional methods is the practical absence of clear methodological approaches to posting for the transport infrastructure objects. This determines necessity of developing a mathematical model of monetary evaluation of roads taking into account specifics of conducting technical expert appraisal. Modification of the conventional approach consists in introducing into the formula (2) the so-called level of qualitative state of the asset in a form of a coefficient (K_{kt}) in accordance with the basic provisions of qualimetry [8, 10].

$$V_{r.a.e.} = V_b \times K_{kt}, \tag{3}$$

where K_{kt} is the level of qualitative state of the asset in a form of coefficient: $K_{kt} \in [0;1,0]$, $\{K_{kt} \in Q\}$; Q is the set of rational numbers.

The level of qualitative state, according to the qualimetric model [10, 16, 17, 20], is defined as coefficient:

$$K_{kt} = \sum_{j=1}^{l} K_j \times m_j', \tag{4}$$

then, respectively

$$K_{kt} = \sum_{j=1}^{l}\left(\sum_{i=1}^{n} P_i \times m_i\right) \times m_j', \tag{5}$$

where K_j is the differential relative indicator of property with coefficient m_j'; P_i is the single differential indicator of qualitative condition of the road; m_i is the weight coefficient of simple properties characterizing qualitative state of the valuated object; m_j' is coefficient of weight of complex

properties characterizing the qualitative state of the valuated object; n is the number of indicators of the road element under consideration, $\{n \in N\}$; l is the number of indicator groups, $\{l \in N\}$.

At each level, any property of the valuated object is quantified by a single (differentiated) indicator of the element qualitative state according to the nomenclature (Fig. 3) by formula (6):

$$P_i = \frac{P_{ia}}{P_{ib}} \ \text{or} \ P_i = \frac{P_{ib}}{P_{ia}}, \tag{6}$$

where P_{ia} is the value of the i-th absolute indicator of the qualitative state; P_{ib} is the value of the i-th base (reference) indicator of the qualitative state.

The qualitative feature determines state of individual structures and structural elements of the road (earthwork, pavement, man-made structures, etc.). According to formula (6), an increase in the single indicator corresponds to improvement of the overall qualitative state of the valuated object, i. e. P_i is a dimensionless quantity determining the level of qualitative state where the best level is equal to one or 100 when represented in percentage. As a rule, three methods are used to establish absolute indicators of qualitative state of the road: experimental, calculation and expert.

The experimental method of determining indicators is the basic method. It provides the most reliable evaluation results. Reliability of the experimental method depends on quality of the measuring means and the number of measurements. For calibrated (state or departmental calibration) measurement means, the indicator reliability depends on the number of measurements. The calculation method is based on experimental determining the indicator of qualitative property and determination of the qualitative state of the valuated object. The expert method is based on the analysis of opinions of highly skilled experts.

Taking into account dependences (4), (5) as well as a possible method for determining the P_i indicators, the level of qualitative state according to the qualimetric model [8, 9, 20] is determined by:

$$f(K_{kt}) = \begin{cases} \sum_{j=1}^{l}\left(\sum_{i=1}^{n} P_i \times m_i\right) \times m_j' \bigg| P_i - \text{is not compared with the standart;} \\ \sum_{j=1}^{l}\left(\sum_{i=1}^{n} \frac{P_{ia}}{P_{ib}} \times m_i\right) \times m_j' \bigg| P_{ia} - \text{the direct indicator;} \\ \sum_{j=1}^{l}\left(\sum_{i=1}^{n} \frac{P_{ib}}{P_{ia}} \times m_i\right) \times m_j' \bigg| P_{ia} - \text{the inverse indicator.} \end{cases} \tag{7}$$

The qualimetric model for assessing the quality level of the road-and-transport infrastructure assets represents a model ordered (decomposed) into a hierarchical structure (into the so-called "tree" of indicators or properties) and constructed in accordance with the basic provisions of the graphs theory [10]. Choice of the number of system levels will depend on the purpose of evaluation and importance of the object. As the number of levels increases, information about the qualitative features of the object and its constituent properties will increase. The multilevel model of the system taking into account the large number of measurements and calculations, should have an optimal number of levels sufficient for evaluation with a given accuracy in accordance with the objective (Fig. 3).

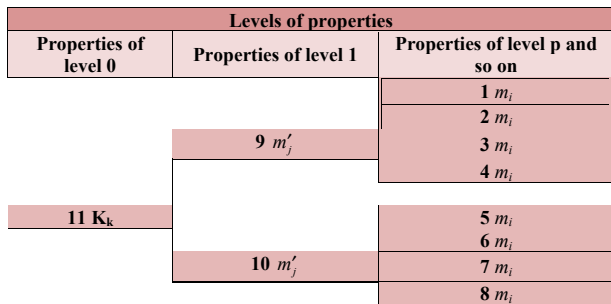| Levels of properties		
Properties of level 0	**Properties of level 1**	**Properties of level p and so on**
		1 m_i
		2 m_i
	9 m'_j	**3** m_i
		4 m_i
11 K$_k$		**5** m_i
		6 m_i
	10 m'_j	**7** m_i
		8 m_i

Fig. 3. Graphical representation of the qualimetric model

The properties of each level influence each other and the generalized properties of one level affect the generalized properties of another level. The complex property at the lowest, zero level is characterized by a set of properties found at higher levels and is a separate indicator. Hence, there is a certain quantitative dependence between the complex index of the qualitative state of the valuated object and the i-th property of the p-th level.

At any level (Fig. 3), each property is estimated not only by the differential indicator but also by the weight coefficient. The latter reflects the value of significance of the differential indicator in the complex indicator. Weight of the properties at any level or in a group of this level obeys the dependence (8):

$$\sum_{i=1}^{n} m_i = k = \text{const}, \qquad (8)$$

where k is a constant value equal to one at fractional values of m_i and is equal to 100 when m_i is represented in percentage.

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

Determination of the weight factors is one of the key tasks that needs to be solved when carrying out evaluation of the road-and-transport infrastructure objects. The weight coefficients are determined by the cost, expert and combined methods. According to the cost method, quality is proportional to the value and the weight is identical to expenses:

$$m_i = f(C_i) \rightarrow m_i = \frac{C_i}{\sum_i^n C_i}, \qquad (9)$$

where C_i is the estimated cost of the i-th structure element of the motorway section; $\sum_i^n C_i$ is the full estimated cost of the motorway section; n is the number of properties of the qualitative indicators of the valuated object.

The expert method for determining the weight coefficients is based on the analysis of opinions of the specialists who evaluate property of the elements of the valuated object. As a result of polling questioning of the experts, initial data (expert estimates) are received from each expert which are then summarized (Table 1).

The group weight coefficients for each property of the object are determined by the relation of the mean expert opinion to the total sum of mean opinions. The weight coefficient of the i-th property of the given group is determined by formula (10):

$$m'_i = \frac{\frac{1}{n}\sum_{i=1}^{n} N_{ij}}{\frac{1}{k}\sum_{j=1}^{k}\sum_{i=1}^{n} N_{ij}}, \qquad (10)$$

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

For each group, the condition described by formula (8) is met.

Table 1

Example of the table of determination of weight coefficients according to the expert opinions

Object property	Expert opinion					Mean opinion, P_i	Sum of mean opinions (in a group)	Group weight coefficient of property m'_j	Coefficient of the indicator weight, m'_i	Level coefficient of the property weight, m_i
	1	2	3	4	n					
1	N_{11}	N_{12}	N_{13}	N_{14}	N_{1j}	P_1	$\sum P_i$	m'_1	m'_1	m_1
2	N_{21}	N_{22}	N_{23}	N_{24}	N_{2j}	P_2	$\sum P_i$	m'_2	m'_2	m_2
...	...	...	...	...	...	...	...	...	...	...
k	N_{i1}	N_{i2}	N_{i3}	N_{i4}	N_{ij}	P_i	$\sum P_i$	m'_j	m'_i	m_i

Following the similar determination of coefficients of indicator weight for each group, the level coefficients of weight of each property are calculated.

In absence of certain elements in the road section (for example, buildings, man-made structures), the weight coefficients of the existing ones are increased:

$$m_{in} = m_i + \frac{\sum_{i=1}^{q} m'_i}{n-q}, \qquad (11)$$

where m_{in} is the new value of the weight coefficient; q is the number of missing elements with weight coefficients m'_i. at the given kilometer of the road.

The coefficient of depreciation will be the indicator inverse to coefficient (K_{kt}) which is an indicator of the qualitative state level:

$$K_{kt} = 1 - K_D, \qquad (12)$$

where K_D is the coefficient of the asset element depreciation (physical and/or functional), $K_D \in [0;1,0]$, $\{K_D \in Q\}$; Q is the set of rational numbers.

Then formula (3) will look like:

$$V_{r.a.e.} = V_b \times (1 - K_D) \qquad (13)$$

or

$$V_{r.a.e.} = V_b - V_b \times K_D = V_b - V_D, \qquad (14)$$

where V_D is the value of depreciation calculated on the basis of the qualitative state.

Reliability of the obtained coefficient of the level of the qualitative state is determined by formula (15) [22]:

$$\Delta K_{kt} = f\left(\Delta K_p; \Delta K_{mi}; \Delta K_{Pi}; \Delta K_j\right), \qquad (15)$$

where ΔK_p is the error of calculation of the number of properties that determine the p-th level in the qualimetric model; ΔK_{mi} is the error of determining the weight coefficients (m_i); ΔK_{Pi} is the error of the degree of accuracy of evaluation of single qualities (P_i); ΔK_j is the error of determining the differential relative indicator of property,

$$\Delta K_j \cong f\left(\Delta K_{mi}; \Delta K_{Pi}\right). \qquad (16)$$

Determination of deviations (errors) is based on the theory of random measurements. Emergence of this or that error is described by the law of normal distribution or by the Student law of distribution [8].

When applying the experimental method for determining absolute indicators of the qualitative state of road assets, statistical characteristics of the errors are estimated by:

1) the arithmetic mean value of the error:

$$\bar{\varepsilon} = \frac{1}{n}\sum_{i=1}^{n}\varepsilon_i, \qquad (17)$$

where n is the total number of measurements;

2) root mean square deviation:

$$\sigma = \sqrt{\frac{\sum\left(\bar{\varepsilon}-\varepsilon_i\right)^2}{n-1}}; \qquad (18)$$

3) the scope of the measurement error:

$$R = \varepsilon_{max} - \varepsilon_{min}, \qquad (19)$$

where ε_{max} is the greatest error value; ε_{min} is the least error value;

4) coefficient of homogeneity:

$$K_H = 1 - \frac{\sigma}{\bar{\varepsilon}} \times t, \qquad (20)$$

where t is the coefficient that corresponds to the probability by the Student's criterion;

5) trust interval:

$$\mu = \bar{\varepsilon} \pm \frac{\sigma_o \times t}{\sqrt{n}}, \qquad (21)$$

where σ_o is the mean value of σ.

Adequacy of the model is characterized by getting of its true (measured) value of the indicator into the confidence interval with a specified probability.

In the case of applying the expert method for determining absolute values of the qualitative state of the assets, statistical characteristics of the errors are estimated by the method of estimation by deviation from the mean, by the method of rank correlation or by the method of concordation [8, 9]. For example, according to the method of concordation, the coefficient that shows consistency between expert opinions and is determined depending on whether the indicators in the estimates of an individual expert are related with the indicators obtained by other experts (i.e., there are identical opinions in at least one row of opinions of at least one of the experts):

$$f(W) = \begin{cases} W = \dfrac{12 \times S}{m^2 \times \left(n^3 - n\right)} & \Big|\, P_{ij} - \text{not related to each other;} \\[4ex] W = \dfrac{S}{\dfrac{1}{12}m^2 \times \left(n^3-n\right) - m \times \dfrac{1}{12}\Sigma\left(t_i^3 - t_i\right)} & \Big|\, P_{ij} - \text{related to each other,} \end{cases} \qquad (22)$$

where W is the coefficient of concordance, $W \in (0;1,0)$; m is the number of experts; n is the quantity of indicators of the qualitative state estimated by experts; t_i is number of elements, the estimate of which is repeated in the row for the i-th expert; S is the value of the sum of deviation squares calculated by the formula:

$$S = \sum_{i=1}^{n}\left(\sum_{j=1}^{m} P_{ij} - P_{cp}\right)^2, \qquad (23)$$

where P_{cp} is the arithmetic mean of the indicator of qualitative state.

Adequacy of the model is characterized by consistency between the expert opinions and, accordingly, by the lowest error in the estimate of the qualitative state indicator achieved by approximating the coefficient of concordance (W) to 1.

4. 3. Development of a mathematical model of evaluation with the possibility of its implementation in the information-and-management system

Let us consider classic methods of evaluation from the standpoint of taking into account the proposed conceptual model of the estimation procedure based on the concept of determining the level of qualitative state.

The method of reevaluation/additional asset evaluation consists in that the asset value is calculated as the product of its initial (start) value of construction and the ratio of the qualitative state of the asset or its element corrected by the inflation index. The condition is the ratio of the current qualitative state of the asset or its element to the better state. The value of assets in the year t is determined by formula:

$$V_{r.r.t} = HC \times \left(\frac{K_{kt}}{K_{kbest}}\right) \times \left(\frac{CPI_t}{CPI_0}\right), \quad K_{kt} \geq 0, \ K_{kbest} \neq 0, \qquad (24)$$

where $V_{r.r.t}$ is the value of the road asset estimated by the method of reevaluation/additional evaluation in the year t, mon. un.; HC is initial (actual) value of construction according to the consolidated estimate, mon. un.; K_{kt} is the level of the qualitative asset state at time t in a form of coefficient: $0 \leq K_{kt} \leq 1,0$, or percentage: $0 \leq K_{kt} \leq 100$; K_{kbest} is the best level of qualitative asset state recorded during its life cycle in a form of a coefficient: $0 \leq K_{kbest} \leq 1,0$ or percentage: $0 \leq K_{kbest} \leq 100$; CPI_t is the construction value indicator in the year t; CPI_0 is the indicator of the construction value in the year when the facility was constructed (according to the Minregion information).

The marginal expense method uses current and past data to determine the value of assets. To calculate the value of assets, the following formula is used:

$$V_{r.m.t} = HC \times \left(\frac{K_{kt} - K_{kworst}}{K_{kbest} - K_{kworst}}\right) \times \left(\frac{CPI_t}{CPI_0}\right), \quad K_{kbest} \neq 0, \qquad (25)$$

where $V_{r.m.t}$ is the value of the road asset assessed by the method of marginal expense in the year t, mon. un.; K_{kworst} is the

worst level of qualitative asset state recorded during its life cycle in a form coefficient: $K_{kworst} \in [0;1,0]$, or percentage: $K_{kworst} \in [0;100]$.

The method of fixed value in relation to the marginal state consists in bringing the state of the asset or its element to the level which consistently exceeds the minimum threshold of productivity set for the given asset.

The asset value is expressed by a constant quantity during its service life until the level of the qualitative state of the asset exceeds certain marginal level. Besides, the value of assets will be zero when the level of the qualitative state drops lower than the set marginal level. In such a case, the issue of renewal or liquidation of the asset is considered.

The asset state is calculated annually at time t (K_{kt}). Experts of the road organization set the limit value of K_{kmt} ($\{K_{kmt} \in K_k\}$; $0 < K_{kt} \leq 1,0$ or $0 < K_{kt} \leq 100$).

For $K_{kt} > K_{kmt}$, the estimated value of a road asset is determined based on adjustment of the replacement (or reproduction) value according to the estimate on the date of assessment by the coefficient of the level of the qualitative asset state. When $K_{kt} \leq K_{kmt}$, a managerial decision is made about the necessity of the asset renewal or liquidation.

The value of a road asset assessed by the fixed value method with respect to the marginal state can be determined by formulas (3) and (13)−(14):

$$f(V_{r.f.t}) = \begin{cases} V_{r.f.t} = RC_t \times K_{kt} = RC_t \times (1 - K_D) = \\ = RC_t - RRC_{kt}, K_{kt} > K_{kmt}, \\ \notin V_{r.f.t}, K_{kt} \leq K_{kmt}, \end{cases} \quad (26)$$

where $f(V_{r.f.t})$ is the function of determining the estimated value of the road asset by the fixed value method in relation to the marginal condition in the year t, mon. un.; RC_t is the value of replacement (or reproduction) of the asset in the year t, mon. un., $RC_t = \sum_{i=1}^{n} C_i$; C_i is estimated value of the i-th element of the road asset which is reproduced in current prices as on the actual date of evaluation using the same architectural decisions, building structures and materials and at the same quality of construction and installation works as for the valuated facility (the cost of reproduction) or using modern materials and in accordance with new standards and planning decisions (replacement cost), $\{i \in N\}$; RRC_{kt} is the depreciation value equivalent to the value of repair and restoration of the asset in the year t, mon. un.; n is the number of elements of the road asset, $\{n \in N\}$.

The method of value transfer consists in determining the value of an asset or its element based on adjustment of the replacement (or reproduction) value according to the estimate as on the date of evaluation by the coefficient of level of the qualitative asset state with no taking into account its marginal level:

$$V_{r.tr.t} = RC_t \times K_{kt} = RC_t \times (1 - K_D) = RC_t - RRC_{kt};$$

$$RC_t = \sum_{i=1}^{n} C_i, \quad (27)$$

where $V_{r.tr.t}$ is the value of the road asset estimated by the method of value transfer with respect to the marginal state in the year t, mon. un.

The estimated value of the road asset is determined in accordance with the structural scheme of determining the level of qualitative state of the valuated object (Fig. 4, block 5).
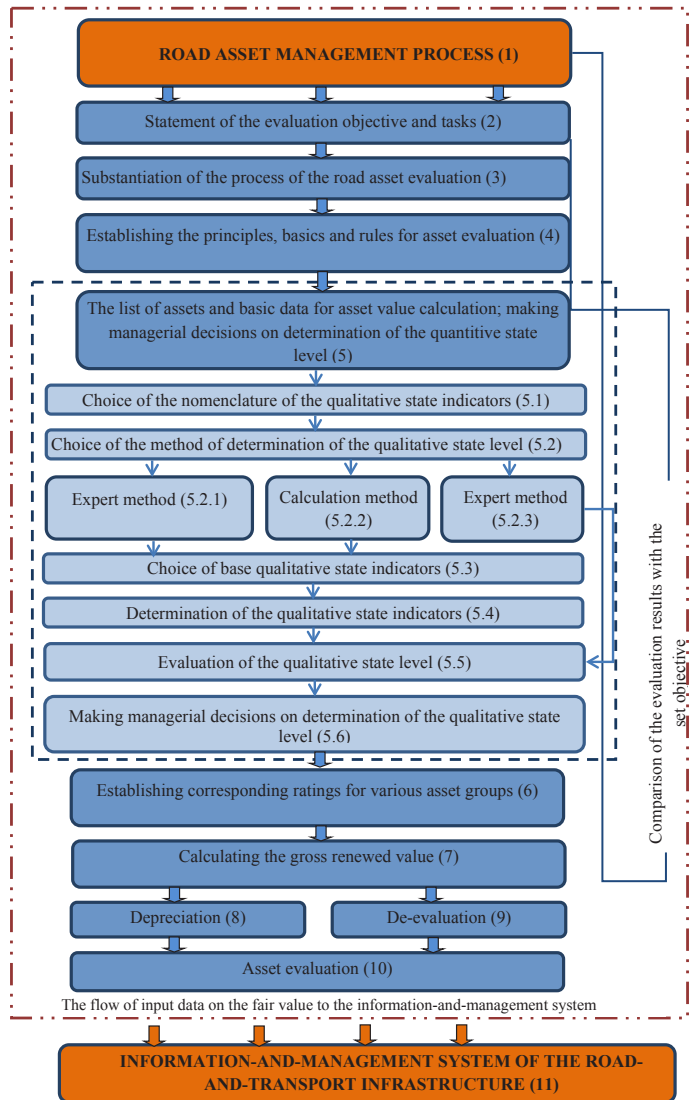

Fig. 4. Conceptual model of the procedure for valuating assets of the road infrastructure

The qualitative state of road assets, like other engineering systems, behaves stochastically as it is influenced by factors that are not deterministic but vary in time and space. One way to include probabilistic elements in the asset evaluation is to provide ranges rather than fixed sums for input evaluation parameters such as replacement value, qualitative state and service life. Thus, forecast of the value of assets at any time t (FV_{it}) taking into account specifics of road assets can be realized on the basis of logistic distribution, Gompertzian distribution, Weibull distribution, gamma distribution or exponential distribution.

For example, the forecast value of assets by the Weibull function can be formalized as follows:

$$FV_{r.tr.t} = (RC_{it}) \times e^{-1 \times \left(\frac{t}{e^{\sum_{j=1}^{j=m} b_j \times x_j}} \right)_\beta}, \{i, m \in N\}, \quad (28)$$

where b_j is the coefficient of the parameter of the j-th property of the road asset element which can be defined as the weight coefficient (m_i); x_j is a variable, the factor of the j-th property of the element that affects the qualitative state level

of an asset and corresponds to P_i in the qualimetric model; β is the distribution parameter.

According to the developed mathematical model, evaluation of assets of the road-and-transport complex should be carried out with the help of the constructed conceptual model in the following sequence (Fig. 4):

1. Determine the object and purpose of evaluation (Fig. 4, block 2). The following can be the criteria for choosing the evaluation purpose:

a) estimate for accounting purposes; in this case, it is necessary to use the method of reevaluation/additional evaluation of the asset or the method of the marginal state;

b) other purposes; if the data on the initial asset value are unavailable, then the fixed value method with respect to the boundary state or the method of the transferred value (replacement or reproduction) is used.

2. Substantiate the evaluation process (Fig. 4, block 3), select the methods depending on the evaluation objective.

3. Establish principles, bases and rules for asset evaluation (Fig. 5, block 4). They must meet requirements of the current legislation on assessment and normative-and-technical documents of the infrastructure sector.

4. Compile a list of assets and basic data for calculating the asset value (Fig. 4, block 5), establish a nomenclature of indicators of the qualitative state by types and groups. Analyze them and select the most significant ones. Assets must be appropriately classified and grouped. Assign the number of levels and construct a model of the qualitative state of the valuated object according to Fig. 3. Select the method and

determine absolute indicators of the qualitative state of the valuated object and the weight coefficients (formulas (6), (9), (10), (11)).

5. Perform initial assessment of the asset value which includes: establishing relevant ratings for various asset groups (Fig. 4, block 6); calculation of a gross renewed value for each asset within a group or a subgroup (Fig. 4, block 7).

6. Calculate losses in the value of assets which involves: determining the level of the qualitative state of the valuated object (formula (7)); calculating the depreciation (Fig. 4, block 8); correcting for de-evaluation during the year and calculating the value loss if necessary (Fig. 4, block 9).

7. Perform evaluation (formulas (24)–(27) depending on the set objectives) (Fig. 4, block 10).

8. Form input data (value indicators) for the information-and-management system of the road-and-transport infrastructure (Fig. 4, block 11).

5. The results obtained in testing the developed mathematical model of evaluation of the road assets

Based on the transferred value method (replacement or reproduction), evaluation of the 1,127-km long state road, category II, was performed. A nomenclature of indicators of qualitative state of the road section at the stage of operation was established by types and groups. The optimal number of levels of the qualimetric model of evaluation of the qualitative state of the road was established (Fig. 5).

LEVEL					
0	**1**	**2**			
		Evenness	0.192	P1	0.047
	Pavement K1	Traction coefficient	0.257	P2	0.063
	0.243	Strengyh	0.261	P3	0.063
		Continuity	0.29	P4	0.07
	Earth roadbed K2	Roadway width	0.653	P5	0.165
	0.253	Roadside width	0.347	P6	0.088
	Parameters of elements in plane and in the longitudinal and lateral profiles of the road K3	Curve radius in the plane	0.188	P7	0.012
		Curve radius in the longitudinal profile	0.209	P8	0.012
		Longitudinal inclination of the road section	0.209	P9	0.012
	0.06	Lateral inclination of the road section	0.185	P10	0.012
		Visibility	0.209	P11	0.012
	Estimate of the environmental impact (hygienic indicators) K4	Exhaust pollution	0.342	P12	0.025
		Noise pollution	0.312	P13	0.024
	0.076	Lighting	0	P14	0
Kkt		Aesthetics	0.171	P15	0.013
		Planting of trees and shrubs	0.175	P16	0.014
	Transport structures K5		0.097	P17	0.097
	0.097				
	Means of traffic organization K6	Railing	0.5	P18	0.044
	0.088	Road signs	0.391	P19	0.035
		Road markings	0.109	P20	0.009
	Objects of road service K7	Footpaths	0.474	P21	0.004
	0.009	Joinings	0.526	P22	0.005
	Objects of road service K8	Bus stops and boarding platforms	0.007	P23	0.007
	0.007				
	Other expenses K9		0.167	P24	0.167
	0.167				

Fig. 5. Qualimetric model of evaluation of the qualitative state of the road asset at the stage of operation

According to the dependences (5), (7), the mathematical model of the level of the qualitative state of the asset (the road section) will look like:

$$K_{kt} = \left(\sum_{i=1}^{4} P_i \times m_i\right) \times m_1' + \left(\sum_{i=5}^{6} P_i \times m_i\right) \times m_2' +$$
$$+ \left(\sum_{i=7}^{11} P_i \times m_i\right) \times m_3' + \left(\sum_{i=12}^{16} P_i \times m_i\right) \times m_4' +$$
$$+ \left(P_{17} \times m_{17}\right) \times m_5' + \left(\sum_{i=18}^{20} P_i \times m_i\right) \times m_6' +$$
$$+ \left(\sum_{i=21}^{22} P_i \times m_i\right) \times m_7' + \left(P_{23} \times m_{23}\right) \times m_8' + \left(P_{24} \times m_{24}\right) \times m_9'. \quad (29)$$

Differential and expert methods were used to transform qualitative features of the valuated object. Development of the conceptual model of the procedure for technical expert appraisal was based on the results of field studies, departmental normative base and the data obtained on the basis of the expert method. The results of field studies included: measuring geometrical parameters of the road section, determining the extent of damage to the pavement and the road structure elements, determining the state of engineering and transport equipment of the road and man-made structures.

When applying the differential method, assessment of the level of qualitative characteristics was carried out by single indicators: the ratio of the indicator of qualitative property to the normative indicator, according to (6).

Mean weight indicators of condition of the road design element were determined by the expert method (Table 3). In applying this method, each property at each level was evaluated not only by the differential indicator but also by the weight coefficient according to Table 1 and formula (10). To determine the weight coefficient, the value method was also used according by formula (9). Requirement of (8) was met at all levels (Fig. 3 and Table 2). Application of such relative quantitative evaluation of qualitative characteristics makes it possible to bring all properties to a single indicator of the model, that is, to transform all simple (quasi-simple) properties by a single scale:

$$K_{kt} = 0,047 \cdot P_1 + 0,063 \cdot (P_2 + P_3) +$$
$$+ 0,07 \cdot P_4 + 0,165 \cdot P_5 + 0,088 \cdot P_6 +$$
$$+ 0,12 \cdot \sum_{i=7}^{11} P_4 + 0,25 \cdot P_{12} + 0,24 \cdot P_{13} +$$
$$_{-} 0,013 \cdot P_{15} + 0,014 \cdot P_{16} + 0,097 \cdot P_{17} +$$
$$+ 0,044 \cdot P_{18} + 0,035 \cdot P_{19} + 0,009 \cdot P_{20} +$$
$$+ 0,004 \cdot P_{21} + 0,005 \cdot P_{22} + 0,007 \cdot P_{23} + 0,167 \cdot P_{24}. \quad (30)$$

According to calculations of indicators of the qualitative road state (column 7) shown in Table 2 and the obtained dependence (30), the single indicator of the qualitative state of the road section at the stage of operation was K_{kt}=66.15 %. Table 3 contains the value of replacement (or reproduction) of the asset in 2017, calculation of the physical wear of the structural road elements and the functional wear according to dependence (26).

Table 2

Determination of indicators of the qualitative state of the road elements and weight coefficients

Object property	Expert judgment					Mean judgement, P_i	Sum of mean judgements	Group weight coefficient of the property, m_j'	Weight coefficient of the indicator m_i'	Level weight coefficient of the property, m_i	Note
	1	2	3	4	5						
1	n/a	n/a	n/a	n/a	n/a	41		0.192		0.047	Evenness
2	n/a	n/a	n/a	n/a	n/a	55	214	0.257	0.243	0.063	Traction coefficient
3	n/a	n/a	n/a	n/a	n/a	56		0.261		0.063	Strength
4	61	61	64	63	62	62		0.290		0.070	Continuity
5	n/a	n/a	n/a	n/a	n/a	94	144	0.653	0.253	0.165	Roadway width
6	n/a	n/a	n/a	n/a	n/a	50		0.347		0.088	Roadside width
7	n/a	n/a	n/a	n/a	n/a	90		0.188		0.012	Curve radius in the plane
8	n/a	n/a	n/a	n/a	n/a	100		0.209		0.012	Curve radius in the longitudinal profile
9	n/a	n/a	n/a	n/a	n/a	100	479	0.209	0.060	0.012	Longitudinal inclination
10	n/a	n/a	n/a	n/a	n/a	89		0.185		0.012	Lateral inclination
11	n/a	n/a	n/a	n/a	n/a	100		0.209		0.012	Visibility
12	n/a	n/a	n/a	n/a	n/a	100		0.342		0.025	Toxicity
13	n/a	n/a	n/a	n/a	n/a	91		0.312		0.024	Noise
14	0	0	0	0	0	0	292	0	0.076	0	Lighting
15	50	60	40	45	55	50		0.171		0.013	Esthetics
16	51	51	48	51	55	51		0.175		0.014	Planting trees and shrubs
17	20	25	25	20	25	23	23	1	0.097	0.097	Transport structures
18	23	22	22	24	23	23		0.5		0.044	Road railings
19	16	18	19	19	18	18	46	0.391	0.088	0.035	Traffic signs
20	5	5	5	5	5	5		0.109		0.009	Road markings
21	26	28	26	28	26	27		0.474		0.004	Footpaths
22	32	30	32	28	30	30	57	0.526	0.009	0.005	Joinings
23	45	48	40	43	45	44	44	1	0.007	0.007	Autopavilions
24	n/a	n/a	n/a	n/a	n/a	100		1	0.167	0.167	Other expenses

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

Table 3

Calculation of physical and functional wear of the road

Item	Design elements	Weight, %	RC_v, UAH 1000	Wear, %	RRC_{kv}, UAH 1000
1	Construction site preparation	2.5	1523.111	n/a	n/a
2	Earth roadbed	25.3	15413.882	21.27	3278.533
3	Transport structures	9.7	5909.670	77	4550.446
4	Pavement	24.3	14804.637	45.4	6721.305
5	Crossings and joinings	0.9	548.320	71.42	391.610
6	Road conveniences	9.5	5787.821	80.92	4683.505
7	Temporary buildings and structures. Funding of other works and expenses	6.9	4203.786	n/a	n/a
8	Customer's personnel payment	2	1218.489	n/a	n/a
9	Design and research works and designer's supervision	2.2	1340.338	n/a	n/a
10	Value-added tax (20 %)	16.7	10174.380	n/a	n/a
	In all	**100**	**60924.434**	**n/a**	**19625.399**
11	Plan and longitudinal profile parameters	6	n/a	3.915	143.111
12	Environmental impact	7.6	n/a	19.933	922.949
	In all	n/a	n/a	n/a	**1066.06**

Note: n/a – indicator not defined

Let us calculate the coefficient of concordance of the expert method by formula (22). For this purpose, it is first necessary to make a composite matrix of ranks $M(P_{ij})$ (Table 4) on the basis of the initial data (Table 2).

Table 4

Summary matrix of the expert opinion ranks $M(P_{ij})$

Object property	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Continuity	61	61	64	63	62
Aesthetic appearance	50	60	40	45	55
Planting trees and shrubs	51	51	48	51	55
Transport structures	20	25	25	20	25
Road railings	23	22	22	24	23
Traffic signs	16	18	19	19	18
Road markings	5	5	5	5	5
Footpaths	26	28	26	28	26
Joinings	32	30	32	28	30
Autopavilions	45	48	40	43	45

Since the matrix contains bound ranks (the same rank number) in the opinions of the expert 3, we will reformat them (without changing the expert's opinion, i. e. the corresponding relationships are maintained between the rank numbers "<", ">", "="). It is also not recommended to put the rank higher than 1 and lower than the value equal to the number of parameters (in this case, n=10). Rank reformatting is shown in Table 6.

In addition, the matrix of ranks $M(P_{ij})$ (Table 4) contains bound ranks in the estimates of experts 4 and 5. Reformatting of the row is the same, according to the example given. On the basis of the reformatted rank rows, a new matrix $M'(P_{ij})$ is constructed (Table 5).

Table 5

Reformatted matrix of the expert opinion ranks $M'(P_{ij})$

Object properties	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Continuity	1	2	3	4	5
Aesthetic appearance	10	10	10	10	10
Planting trees and shrubs	8	9	7.5	8	8.5
Transport structures	3	4	4	3	4
Road railings	4	3	3	4	3
Traffic signs	2	2	2	2	2
Road markings	1	1	1	1	1
Footpaths	5	5	5	5.5	5
Joinings	7	7	7.5	7	7
Autopavilions	9	8	9	9	8.5

Table 6

An example of reformatting the expert's ranks at bound ranks in the indicator opinions

The order number of the factor in the ranked row	Expert opinion	New rank
1	5	1
2	19	2
3	22	3
4	25	4
5	26	5
6	32	6
7	40	7.5
8	40	7.5
9	48	9
10	64	10

Then, with the help of MS Excel or Mathcad, the magnitude of the sum of squares of deviations of the qualitative state indicators can be calculated. It is $S=2029.5$ in this case.

Determine the coefficient of concordance by formula (22):

$$W = \frac{2029,5}{\frac{1}{12}5^2 \times (10^3 - 10) - 5 \times 1,5} = 0,99. \qquad (31)$$

The coefficient of concordance $W \neq 0,$ therefore there is consistency between the experts. The value of the coefficient $W=0.99$ indicates presence of a high degree of consistency of the expert opinions which confirms reliability of the input data to the developed qualimetric model.

Assessment of the significance of the concordance factor can be checked by the Pearson criterion calculated in MS Excel using the built-in PEARSON function. Thus, Pearson's criterion was $\chi^2 = 44,44.$ Let us compare the calculated value with the table value for the number of degrees of freedom $k = n - 1 = 10 - 1 = 9$ and at the level of significance $\alpha = 0,05.$ We have $\chi_T^2 = 16,91898,$ that is $44.44 > 16.91898,$ therefore $W=0.99$ is not random quantity and the obtained results are reliable and can be used in further studies.

6. Discussing the results of creating a mathematical model of asset evaluation as a component of the information-and-management system

Test of the mathematical model of the road asset evaluation has shown that:

1) the proposed approaches to determining the level of the qualitative state of the object make it possible to fully take into account the influence of qualitative indicators of the asset on its evaluation, in contrast to the conventional approaches;

2) reliability of the calculations made according to the mathematical model depends to a great extent on the established system of indicators and assessment of adequacy of the input parameters which is not done with the conventional model;

3) input parameters of the mathematical model were suggested to be determined by three main approaches: experimental, calculation and expert which must be necessarily analyzed for reliability in order to minimize errors and increase significance of the qualitative state indicators;

4) the constructed qualimetric model allows one to effectively simulate parameters of the mathematical model of valuating the qualitative state of assets of the road-and-transport infrastructure;

5) in turn, the mathematical model enables determination of a fair asset value at the time of estimation taking into account the sector specifics; it increases quality of information provided to the management of the road-and-transport complex.

Unlike the proposed model, the conventional mathematical model of asset evaluation consists in adjustment of the base value by deducting physical and/or functional wear. In the country, there are no individual methodological approaches to valuating objects of the road-and-transport infrastructure. Such objects are valuated by the general approach and calculations are based on global norms established in the Soviet period. Expert appraisal data are not duly processed in road evaluation. The developed mathematical model, unlike conventional one, suggests to take into account physical wear not as a calculated normative value but as a result of estimation of the level of qualitative state of the asset obtained in technical examination. Moreover, basic provisions of qualimetry are used in this case which was not previously used in evaluation. The disadvantages of application of the developed mathematical model can include the errors of calculation of the number of properties that determine levels in the qualimetric model, the errors of determining weight coefficients, the degree of accuracy of evaluation of individual qualities, determination of a differential relative indicator of property. In particular, when applying the expert method, there may be difficulties in obtaining a reliable and consistent estimate, the expert subjectivism may take place. Therefore, this study proposes to evaluate the model for its adequacy and the input parameters for their reliability. When applying the expert method in determining parameters of the model, it is proposed to assess the level of competence of the experts. Despite these shortcomings, it has been experimentally found that when applying the developed mathematical model, reliability of the model parameters is rather high and, consequently, the model adequacy is proved.

The results of these scientific studies will be used for further improvement and development of scientific investigations in the field of management of the national road-and-transport complex. These materials will be a real tool for conducting expert examination and road asset evaluation. The results of road asset evaluation may serve as pre-project materials and an informational base for development of projects of reconstruction, overhaul, repair and maintenance of the operated roads.

7. Conclusions

1. Components of the asset evaluation process as an element of management of the road-and-transport complex were determined. A conceptual model of the procedure for valuating assets of the road infrastructure has been constructed. The proposed model makes it possible to perform evaluation of the road infrastructure assets not according to the conventional approach but from the position of uniqueness of linearly extended objects and the specifics of the road-and-transport complex. The model takes into account impact of the level of qualitative state and the estimated value on the process of making managerial decisions pertaining to road assets.

2. The conceptual model of the procedure for asset evaluation was constructed taking into account level of the qualitative state. The conceptual model is based on the use of a qualimetric model and a multilevel hierarchical system of indicators. Criteria and indicators of property evaluation, inventorying the road sections were substantiated. Weight coefficients for each differential indicator of the qualitative state of the road structure elements and other facilities located within the right of the way zone were determined based on the value and expert methods. A multilevel hierarchical system of indicators that comprehensively and rationally characterizes qualitative attributes of the valuated object or the road section was

elaborated. The complex indicator grouping all differential indicators and simple product properties at the highest model level was substantiated.

3. The mathematical model of asset evaluation was constructed as a component of the information-and-management system of the road-and-transport infrastructure. The presented results form the base for working out method-ological approaches and information analysis systems for evaluation of specialized assets of the Ukrainian road-and-transport complex. In particular, the results of this scientific study were taken as the basis of elaboration of Methodological Recommendations for Evaluation of Motorways and Their Structures (MR D 1.2-37641918-884:2017). The first edition of this document can be found in [29].

References

1. McPherson, K. Success Factors for Road Management Systems. Version 1.0 [Text] / K. McPherson, C. R. Bennett. – East Asia Pacific Transport Unit. The World Bank. Washington, D.C., 2005. – 111 p.

2. Hordijk, A. C. Real Estate Appraisal and International Valuation Standards [Text] / A. C. Hordijk // XLI Incontro di Studio del Ce.S.E.T. – 2012. – P. 397–401. – Available at: http://www.fupress.net/index.php/ceset/article/viewFile/13150/12437

3. Markus, Ya. I. Mify i realii otsenki imushchestva [Text] / Ya. I. Markus // Visnyk Prydniprovskoi derzhavnoi akademii budivnytstva ta arkhitektury. – 2013. – Issue 7. – P. 8–12.

4. Fedorovych, R. Neobkhidnist vykorystannia vartisnykh metodiv v upravlinskykh tekhnolohiyakh [Text] / R. Fedorovych, I. Seredynska // Halytskyi ekonomichnyi visnyk. – 2013. – Issue 3 (42). – P. 60–72.

5. Dojutrek, M. S. A Methodology for Highway Asset Valuation in Indiana [Text] / M. S. Dojutrek, P. A. Makwana, S. Labi // Joint Transportation Research Program. – Indiana Department of Transportation and Purdue University, West Lafayette, Indiana, 2012. doi: 10.5703/1288284315035

6. McNeil, S. Asset Management and Asset Valuation: The Implication of the Government Accounting Standards Bureau (GASB) Standards for Reporting Capital Assets [Text] / S. McNeil // Midcontinent Transportation Symposium. – Minnesota, 2000. – P. 34–37.

7. Switzer, A. Developing a Road Map for Transportation Asset Management Research [Text] / A. Switzer, S. McNeil // Public Works Management & Policy. – 2004. – Vol. 8, Issue 3. – P. 162–175. doi: 10.1177/1087724x03259475

8. Sidenko, V. M. Upravlenie kachestvom v dorozhnom stroitel'stve [Text] / V. M. Sidenko, S. Yu. Rokac. – Moscow: Transport, 1981. – 252 p.

9. Kaveshnikov, N. T. Upravlenie kachestvom produktsii (na primere vypolneniya dorozhno-stroitel'nyh rabot) [Text]: ucheb. pos. / N. T. Kaveshnikov. – Moscow: Moskovskiy gosudarstvenniy universitet prirodoobustroystva, 2000. – 105 p.

10. Azgaldov, G. G. The ABC of Qualimetry: The Toolkit for measuring immeasurable [Text] / G. G. Azgaldov, A. V. Kostin, A. E. P. Omiste. – Ridero, 2015. – 167 p.

11. Trishch, H. M. System of dependencies for assessment of enterprises quality management processes [Text] / H. M. Trishch // Eastern-European Journal of Enterprise Technologies. – 2013. – Vol. 4, Issue 3 (64). – P. 60–63. – Available at: http://journals.uran.ua/eejet/article/view/16283/13802

12. Katrych, O. O. Scientific approaches to quality assessment processes [Text] / O. O. Katrych // ScienceRise. – 2015. – Vol. 4, Issue 2 (9). – P. 69–72. doi: 10.15587/2313-8416.2015.41589

13. Lapidus, A. Fuzzy sets on step of planning of experiment for organization and management of construction processes [Text] / A. Lapidus, A. Makarov // MATEC Web of Conferences. – 2016. – Vol. 86. – P. 05003. doi: 10.1051/matecconf/20168605003

14. Kanin, O. P. Sutnist ta pryznachennia informatsiyno-analitychnykh system upravlinnia dorozhnim hospodarstvom Ukrainy [Text] / O. P. Kanin, A. M. Kharchenko // Upravlinnia proektamy, systemnyi analiz i lohistyka. – 2012. – Issue 9. – P. 71–78.

15. Kanin, O. P. Upravlinnia dorozhnim hospodarstvom shliakhom zastosuvannia informatsiyno-analitychnoi systemy [Text] / O. P. Kanin, A. M. Kharchenko // Informatsiyni protsesy, tekhnolohiy ta systemy na transporti. – 2014. – Issue 2. – P. 98–102.

16. Slavinska, O. S. Metodolohya mainovoi otsinky avtomobilnoi dorohy, yak obiekta derzhavnoi vlasnosti [Text] / O. S. Slavinska // Avtomobilni dorohy i dorozhnie budivnytstvo. – 2016. – Issue 97. – P. 70–76.

17. Bubela, A. V. Vykorystannia dyferentsiynoho metodu v proektakh budivnytstva avtomobilnoi dorohy dlia obliku ta otsinky aktyviv dorozhnoho hospodarstva [Text] / A. V. Bubela // Avtomobilni dorohy i dorozhnie budivnytstvo. – 2016. – Issue 98. – P. 22–29.

18. Slavinska, O. S. Application of transformation assessment tasks highways managment methodology of property evalution road on the basis of transformation [Text] / O. S. Slavinska // Roads and road construction. – 2016. – Vol. 96. – P. 104–111.

19. Bubela, A. V. Project management of estimates of the roads based on considerstion of the technical state [Text] / A. V. Bubela // Roads and road construction. – 2016. – Vol. 97. – P. 50–55.

20. Slavinska, O. S. Zastosuvannia kvalimetrychnoi modeli do otsinky transportno-ekspluatatsiynoho stanu avtomobilnoi dorohy [Text] / O. S. Slavinska, A. M. Kharchenko // Avtomobilni dorohy i dorozhnie budivnytstvo. – 2016. – Issue 95. – P. 111–120.

21. Savenko, V. Ya. Upravlinnia yakistiu tekhnichnoho stanu avtomobilnoi dorohy na osnovi zastosuvannia metodu defektiv pry mainovi otsintsi [Text] / V. Ya. Savenko // Avtomobilni dorohy i dorozhnie budivnytstvo. – 2016. – Issue 97. – P. 63–70.

22. Parli, R. L. The education of a profession [Text] / R. L. Parli // The Appraisal Journal. – 2007. – Vol. LXXV, Issue 4. – P. 326–338.

23. Falls, L. C. Asset Valuation as a Key Element of Pavement Management [Text] / L. C. Falls, R. Haas, J. Hosang // 5th International Conference on Managing Pavements. – Seatle, 2001.

24. Falls, L. C. A Framework for Selection of Asset Valuation Methods for Civil Infrastructure [Text] / L. C. Falls, R. H. Tighe // Annual Conference of the Transportation Association of Canada. – 2005.

25. Dewan, S. A. Valuing Pavement Network Assets and Use of Values as Decision Supports [Text] / S. A. Dewan, R. E. Smith // Journal of Infrastructure Systems. – 2005. – Vol. 11, Issue 4. – P. 202–210. doi: 10.1061/(asce)1076-0342(2005)11:4(202)

26. Clarke, H. A Conceptual Framework For The Reform Of Taxes Related To Roads And Transport [Text] / H. Clarke, D. Prentice. – La Trobe University, for Australia Treasury Australia's Future Tax System, 2009. – 104 p. – Available at: https://taxreview.treasury.gov.au/content/html/commissioned_work/downloads/Clarke_and_Prentice.pdf

27. Dutzik, T. Do Roads Pay for Themselves? Setting the Record Straight on Transportation Funding [Text] / T. Dutzik, B. Davis, P. Baxandall. – U.S. PIRG Education Fund, 2011. – 45 p. – Available at: https://uspirg.org/sites/pirg/files/reports/Do-Roads-Pay-for-Themselves.pdf

28. Litman, T. Environmental Reviews & Case Studies: Why and How to Reduce the Amount of Land Paved for Roads and Parking Facilities [Text] / T. Litman // Environmental Practice. – 2011. – Vol. 13, Issue 1. – P. 38–46. doi: 10.1017/s1466046610000530

29. Proekt pershoi redaktsiy MR D 1.2-37641918-884:2017 [Electronic resource]. – Available at: http://dorndi.org.ua/uk/2017/10/03/%D0%BF%D1%80%D0%BE%D0%B5%D0%BA%D1%82-%D0%BF%D0%B5%D1%80%D1%88%D0%BE%D1%97-%D1%80%D0%B5%D0%B4%D0%B0%D0%BA%D1%86%D1%96%D1%97-%D0%BC%D1%80-%D0%B4-1-2-37641918-8842017/