UDC 332.012.23

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Systemic causes of discrepancies in the valuation of an industrial asset by the independent approaches and the recommendations for the valuation results harmonizing

The assessment of the value of industrial assets is carried out to make decisions when forming complexes of these assets as part of the businesses of acting enterprises, as well as when creating the assets themselves, when purchasing them, when decommissioning for recycling and for the other assignments. The valuation error and the discrepancy between the value of these assets found by independent approaches indicates the quality of the valuation. The base of the error determining in estimating the value should be adjusted depending on the age of the industrial asset and it accumulated depreciation, since the value of asset within it lifetime decreases to zero with age and therefore this cannot serve as a base for finding of the value relative error. The causes for the discrepancy between the value of an industrial asset and its value found by independent approaches are both the approximateness of the initial data, which, when assessed, replace the characteristics of the general system, in which the assessed asset enters as the subsystem, and the methodological differences of the value normative concept and the value as the set of methods of it determining by the independent approaches. For adjusting the results found by each independent approach, an analysis is carried out of their compliance with the adequate methodological concepts of valuation and the performances of industrial asset. Taking into account the property of accumulation of the depreciation and the limited durability of the asset, the distribution of it values got by the cost and the income approaches, when harmonizing they, can be rationalized using the considered method. After an expert determining of the weight coefficient of the result got by the comparable sales approach, the contributions of the independent results got by cost and income approaches are adjusted in proportion to the transfer of accumulated net income to the value of property complex to which the industrial asset belongs as element of the system.
Keywords: *industrial asset, property complex, purpose of an asset, durability of an asset, value change, independent approach, property complex, element of a complex, system communication, data error, concept of value, determining of value, conformity of definitions, harmonization of value, transfer of value, economic obsolescence*

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INTRODUCTION

In order to increase capitalization, the company creates complexes of assets, uses them productively and disposes of them. The separate Industrial assets included in the company's property complex have limited durability, they are acquired, used, and disposed of as the value is transferred to the accumulated net income. The company operates on the basis of financial self-sufficiency, while net income and profit are kept in the property complex of assets and serve its value growth.

Due to external or other circumstances the complex of assets in the long term is also restructured. But the limitation of durability, which is associated with indicators of accumulated irremovable wear, is a property of only a part of the property complex — its industrial asset, while the whole — the property complex does not have internal limitations of durability in the terms of systemic approach models [1], and the value of the complex grows as assets are accumulate.

An example of an estimated industrial asset (the separate one in the set of property complex) is to be real estate [2], machinery or equipment [3], or the intangible asset [4, 5]. At the same time, it would be unnatural to classify complex objects as industrial assets and it would be illogical to consider complex real estate in the sum of its parts, for example, a building and a built-up area as the industrial asset. In this example, only a building could be classified as an industrial asset, assuming it assignment, while the site is a universal part of a complex facility.

Among the methodological elements that influence the applied approaches for the valuation of industrial assets, one can also indicate the characteristic decrease of an industrial asset value with age, considering the limited durability of the asset, which is not completely characteristic of complex objects, such as an integral operating enterprise, or as real estate, the value of which usually does not decrease less than the value of the occupied site (up to the cost of clearing the site — in some estimates).

Limited durability is not an obligatory characteristic of a property complex whose assets are replaceable and economically viable. It is characteristic that durability is an important property of the industrial asset in the set of property complex of the acting company, and this property must be taken into account when determining the asset value.

The concept of an industrial asset, which is other than the complex one, that is, the integral property complex of acting company, is associated with the characteristic of the asset assignment, usually indicated in the asset passport or in it

performances specification. Examples of the characteristics of purpose of the industrial asset can be: assignment of a building, type of vehicle or machine, assignment of an equipment object, of a particular intellectual product, and so on.

On the other hand, the assignment of a complex asset (i.e., an integral property complex), characterizing the type of activity of the enterprise, usually corresponds to the code according to the Classifier of Economic Activities. For any type of economic activity in the set of property complex of company there are the industrial assets of various assignments — both the real estate and the equipment.

In some cases, a synonym for the name: an industrial asset could be considered a close concept of the separate asset, although the term "the industrial asset" seems to be more correct, since the separate could mean one valued outside the property complex, which is not typical.

It has to be indicated that among the features of an industrial asset valuation, the value of which can be determined by the independent approaches, including the income one (in accordance with the Standard for Valuation or with the methodic papers [6–16]), the opportunity is assumed of the asset independent financial accounting.

When harmonizing the results of valuation by independent approaches, it should be taken into account that there is an uncertainty factor, which, when assigning weight factors or the coefficients (weights) to the results of valuation by independent approaches, is decided by experts, and there are no rigorous mathematical methods for distributing weights, which is an uncertainty factor. The uncertainty of the correlation of got results of valuation by independent approaches is theoretically unavoidable, in particular, it is impossible to create a strictly evidential mathematical method for determining weight coefficients, and any expert methods for assigning these coefficients are subjective to one degree or another. Expert assignment of weight coefficients in solving of the economic problems with uncertainty, both when finding the indexes of value so when the indicators of economic efficiency, is a normal way of independent results coordinating, taking into account the uncertainty factor, this usually has the form of composite economic index (the formula 23.13 [3]). And if the weight coefficients serve as characteristics of the confidence probability, which is also a rather subjective indicator, then the harmonizing of the results of valuation meets the Laplace criterion known in math.

THE GROUND OF COMPARISON WHEN DETERMINING THE VALUATION RELATIVE ERROR

The error of asset valuation can be determined in absolute value (in monetary units) by variant calculations and in relative units — without dimension. The dimension of the absolute error of valuation is to be eliminated when using the monetary comparison index. To find the valuation error by relative value, it would be necessary to define the concept and to use the defined index of the comparison base in units of value, without confusing the base for determining the relative valuation error with the indicator of the valuation base — the market value.

Since, unlike the property complex, which is an renewable set of all assets of the acting company, the durability of the industrial asset is usually limited and the value of each asset within the limits of it durability usually reduces almost to zero, then the basis for estimating the error in these cases should not be the value sought and the any sustainable index, when the value changes over time, for example, the index of sum of the value gradually reduced and the accumulated depreciation of the asset, or the total of costs for creating of the asset analogue in market prices, i.e. it replacement cost.

With limited durability, the market value of the industrial asset in the present prices by the time is reduced to almost zero, since the residual liquidation value, that is the utilization one, and the cost of disposal are commensurate with estimation error of zero value compared to the market cost of creating an asset (the replacement cost).

On the other hand, it must be taken into account that depreciation accumulates with age of the asset. Since it is assumed that the error in relative value should not grow indefinitely as wear accumulates and value decreases, then, accordingly, the absolute (monetary) error of the value determining should decrease to zero in proportion to the decrease of value as it is, if value is taken as the comparison base when finding the relative error of the value determining.

But in this case, a methodological contradiction would arise, consisting in the fact that in terms of monetary (absolute) error of estimate of the value, which decreases by the age to zero, which is also the error in determining accumulated depreciation, formally cannot be zero, because the comparison base for determining the relative error of depreciation would be growing by the asset age the depreciation, which tends to the maximum, when the value tends to zero.

Therefore, the value of an industrial asset, which becomes cheaper to zero within the limits of durability, cannot be a basis for comparison to determine the relative error of value estimate. In other words, when determining the error in terms of a relative value it is advisable as a base of comparison to take some economic indicator that is not corresponded with durability of the industrial asset and does not change significantly by the age of the asset that is by the depreciation accumulation, for example, consider the error of the value estimate in relation to the asset replacement value (the market costs for creating a new analogue) or the sum of the market value and the accumulated depreciation as the comparison base of the relative error.

Should be explained with an example. Let's say by the cost approach the value of asset is rated 100 thousand US dollars, by the income approach — 200 thousand US dollars, and by the comparable sales one — 300 thousand US dollars, and the replacement costs is 5 million US dollars. Despite the apparent spread of values: 100, 200 and 300 thousand US dollars, with an average estimate of 200 thousand US dollars, this value is a quite satisfactory approximation of zero value of the asset compared to its replacement costs (5 million US dollars), or compared to the sum of the value of the asset and its accumulated depreciation, which for the considered example is almost equal to the replacement costs, and this serves as a hint that the asset value corresponds to zero or to the residual liquidation value, and the spread of values is quite acceptable if the replacement costs is taken as the basis for comparing the relative error, or the found sum of value and accumulated depreciation is taken as this basis.

In terms of reliability for such an example the estimate by independent approaches could raise much more doubts, in which the results would be: 190, 200 and 210 thousand US dollars, which could mean an incredibly high accuracy of the assessment compared to the replacement value (5 million US dollars), or compared to the sum of the found value (200 thousand US dollars) and accumulated depreciation, and this would lead to the incorrect conclusion that the value of asset is equal to 200 thousand US dollars,

when in reality it corresponds to zero or to residual liquidation value, and 200 thousand US dollars is a value commensurate with the absolute error of value estimate, which, when determining the relative error, should have been attributed to the replacement costs or to the sum of the market value and accumulated depreciation, which indicated by data of considered example.

Thus, when finding the estimation error by it relative value, it is necessary to specify correctly the base of this error from the standpoint of the systemic approach, in which an industrial asset is evaluated not by itself, but as an element of cyclic system: creation, installation, equipment and it launch, productive use, maintenance, write-off and disposal, and the relative error base is that associated with the estimated value index, which somehow remains unchanged or sustainable during the specified systemic cycle.

THE CAUSES OF VALUATION ERROR

When studying the quality and accuracy of the industrial asset value assessing it is necessary to take into account both natural errors arising from inaccurate data and the methodological discrepancies.

The inaccuracy of the data: the constraints and the assumptions of evaluation, including the data used in the creation of mathematical models, programs, databases, etc., used in the value determining, underlies the natural errors of its finding and is of a systemic nature, since the asset is examined when determining the value as an element of a certain more general system and, at the same time, as a system consisting of it elements — the subsystems.

Theoretically, the list of examples of a more general system than the asset being valued is unlimited. As examples of the characteristics of more general systems than the asset being valued, when evaluating a land plot or an object on a site, one can indicate: address, cadastral quarter, municipality, subject of the federation and so on. An industrial asset is valued in the system of all the links — in the set of property complex or as part of one or another operating technology, as a product of serial or individual production, as an investment object within the framework of a corresponding innovative project, as a certain type in one or another asset classification system and etc.

For practical purposes, when determining the value of an asset, one has to adhere to the constraints and the assumptions, corresponded with the characteristics of more general system, to which the asset being valued belongs as the subsystem. These constraints serve as the initial data for evaluation, and the reason for the data error is their known relativity, which arises as a result of the break of methodological links between the industrial asset and the more general system to which it belongs in a functional, technological, economic, legal or other respect, and the number of variants of this system is in principle unlimited.

A typical example of a system that is more general than the industrial asset being valued, to which it belongs, can be indicators of the property complex to which the asset or the object of equipment being valued belongs. In turn, this property complex is included in the composition of the more general system as it element, for example, in the composition of a particular industry sector or regional economy. In this inductive sequence it would be possible to enlarge systems and complex objects that include an industrial asset. And in the practical determining of asset value, such a sequence of entry into more general systems is substituted by the valuation constraints, that is, the initial data in the form of certain numerical indexes, in the form of models created for valuation and used, or in the form of rules and limits of applicability of the initial data and these constraints, as indicated above, are largely conventional due to the variety of options and degrees of generalization of systems in which the valuated object is included as an element, and the specified relativity causes the data errors — the inaccuracy of the constraints and the assumptions of valuation.

In turn the industrial asset from the systemic point of view also acts as a complex object consisting of subsystems. In particular, a property complex consists of separate industrial assets, while real estate consists of a built-up area and a building, also consisting of separate parts and rooms, and, further in deductive sequence, parts of an asset include separate structural elements and so on.

In practical tasks, when determining value the data of the constituent parts of this asset for each level of detail are also used as the constraints in addition to the characteristics of more general systems to which the industrial asset belongs as an element, and the relativity of the chosen level of detail and the corresponding breaks of methodological links of the industrial asset and its subsystems are the cause of the error of these data, just as the cause of the error is the relativity of data when they replace the methodological links of valuated asset with the general systems to which the asset belongs as an element, which is considered above.

That is, the inaccuracy of the data factors for estimating value are the following:

- the degree of relativity (the conventionality) and corresponded approximation of data, i.e. the constraints and the assumptions, including those adopted in the assessment methods and models used, which, when determining the value, replace the methodological links of the industrial asset with more general system to which it belongs as an element;
- the approximate nature of the parameters assigned when determining the asset value, which replace the methodological links of the asset with it subsystems.

To assess the impact of data or parameter errors on the accuracy of finding the value of industrial asset, one can use the variant calculations of value when varying data and parameters within their errors. At the same time, the cause of error in the results of these variant calculations will not be the discrepancy between the methodological assumptions of independent approaches for the same and combination of data (the constraints and the assumptions).

THE ANALYSIS OF CAUSES OF THE DISCREPANCIES OF VALUATION BY THE INDEPENDENT APPROACHES

Different values found by independent approaches may indicate the methodological discrepancy between these results, which cannot be considered as valuation error, corresponded with approximation and inaccuracy of data and models, used to valuate an industrial asset.

The analysis of characteristic forms of dependences of the value of industrial asset on its age when valuated by independent approaches (Fig. 1) indicates that in wide ranges of age variation, correlated with the accumulation of the irremovable depreciation, the values found by the independent approaches differ by the ranges commensurate with these values as they are.

For some ages within the limits of durability of the industrial asset the independent approaches together can give a similar value: the same estimates of value can be determined by the income and the comparable sales approaches at a certain age of the asset (marked *A* on the chart, Fig. 1), and for other age of the asset the common value is given by cost and income approaches (on

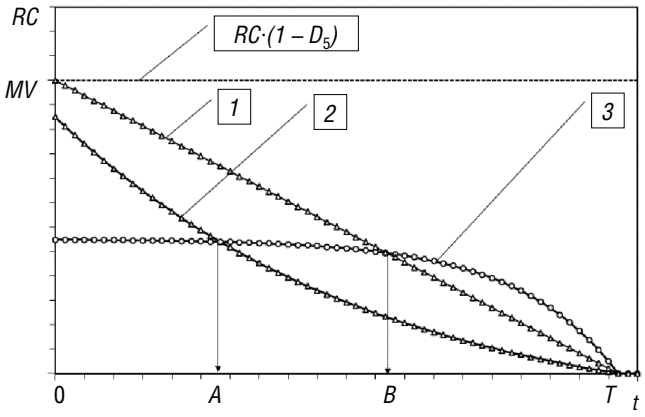

Fig. 1. Dependences of the industrial asset the values MV on the age t within durability T when finding by: 1 — the cost approach; 2 — the comparable sales approach; 3 — the income approach; A, B — the age values for intersections of graphs of estimates by independent approaches; RC·(1 – D_5) — the replacement cost deducted the external obsolescence

the chart *B*). As can the schematic graphs indicate three independent approaches can give the same zero value for the conditions for an asset decommissioning, for example, when determining the residual liquidation value (the utilization one).

For the age of an industrial asset corresponding to the values *A* and *B* (Fig. 1) the results of value estimation in one or another pair of independent approaches are close. These ages of the asset and the range of values between them may just correspond to the characteristic sales on second-hand market. And for other values of age (less than *A* and more than *B*, as well as between *A* and *B*) according to the schematic graph, the discrepancies in the estimates by independent approaches are characteristic.

That is, if there is one or another preferred approach outside the range of values of the "market" age of the industrial asset (from *A* to *B*) then the values estimated by the other approaches would probably degrade the quality of the estimate compared to this preferred approach estimate.

The discrepancies in values found by independent approaches have systemic causes that go into the problem of correspondence of market value two methodological definitions:

- on the one hand, the definition of value as the result of a consistent assessment by independent approaches in accordance with standards, in particular, with the Standard for Valuation "General concepts of valuation, approaches to valuation and assumptions for conducting valuation", what could be considered a methodical (algorithmic) definition of value;
- on the other hand, value in its normative definition under Russian Federal Law of July 29, 1998 No. 135–FZ "On valuation activities in the Russian Federation" and under the corresponded Article of Standard for Valuation "The purpose of the valuation and types of value" as "… the most probable price at which the object of appraisal can be alienated on the open market in a competitive environment, when …", or other standards, including all terms of the normative definition used.

In contrast to considered error of value estimate due to inaccuracy of data and the systemic relativity of the asset coordination as the element in the general system, as well as the conventionality of links of the asset with it subsystems, the cause of observed discrepancy of values found by independent approaches arises due to the methodic difference of value definitions given above, i.e. the value definition as a result of the coordinated use of three (or other number) independent approaches, which should naturally lead to finding the value in definition of it normative concept.

In practical evaluation, the correspondence of these two definitions of the value is considered as an axiom and no exact proof is known that the consistent application of the three standard approaches gives value in its normative definition.

At the basis of the observed discrepancies of values found by independent approaches, there is a methodological difference between these approaches. Indeed, if only one approach would have been prescribed by the valuation standards, then the discrepancies in the obtained values would not emerge, and there would be no reason to doubt the conformity of value as the consistent use of three independent approaches, on the one hand, and value in its normative definition by the federal law and valuation standards, on the other one.

In a historical retrospective the periods are known in which it would has been logical to correlate the value with the presumptions of the cost approach, since the sale of property with profit, in particular, did not correspond to the morality of the religious worldview common in the Middle Ages, in which profit acts as illicit enrichment, which quite closely corresponds to the philosophy — Thomas Aquinas. Such ethical canons could mean the impermissibility of speculative profit and the acceptability of only the cost approach when finding value as the sum of costs spent. Although, it would probably be accepted as the allowable wear of the goods and the own contribution of labor to the material costs incurred. If for these conditions it is assumed that estimating by the income approach is unacceptable, then the cost approach, which includes the comparable sales one — to determine the initial costs, would remain as the only acceptable way to determine value. At the same time, there would be no doubts about the compliance of the normative concept of value as the sum of costs and the value methodical determination by costs summation of acquiring or creating an industrial asset minus it depreciation.

It can be seen that the question of a possible discrepancy between the normative concept of value and it methodological definition as the result of harmonized use of the independent approaches emerges simultaneously with the question of the correspondence of the independent approaches to each other. These two interrelated issues essentially represent a single problem, in which the correspondence of value as a concept and as a standard algorithm for its determination is characterized by a divergence of results when applying independent approaches.

Both the indicated methodological discrepancy in the assessment by independent approaches and the error in determining value due to inaccurate data are natural properties of the value index of an industrial asset.

To observe the discrepancy between the results of valuation when plotting the schematic graphs (Fig. 1) the characteristic forms of dependences of value on the age of the industrial asset were taken into account when it was evaluated using the cost, the comparable sales and the income approaches.

THE CHARACTERISTIC DEPENDANCE ON ASSET AGE OF VALUE DETERMINED BY COST AND COMPARABLE SALES APPROACHES

It is logical to make a general analysis of the dependencies of asset value on the age, taking into account the commonly used formulas. The cost approach value *MV* of the industrial asset in dependence on it reconstruction costs *RC* and the indexes of depreciation one can find according to the known formula [7]:

$$MV\left(D(t)\right) = RC\left(1-D_2\right)\times \\ \times\left(1-D_4\right)(1-D_5)-D_1-D_3, \quad (1)$$

where D_2, D_4 and D_5 — the irremovable depreciation physical, functional and external; D_1 and D_3 — the removable depreciation: physical and functional, usually valued in terms of money, as opposed to permanent depreciation, determined by relative value.

The irremovable depreciation physical D_2 and functional D_4 accumulate with the age of an industrial asset, for example, according to a linear or other proportional dependence, which corresponds to the method of depreciation determining often used in practical assessment, having into account the durability (life) of an asset and it age, and also corresponds to depreciation in the book keeping. The indicated proportion could be attributed in total to the accumulated irremovable physical and functional depreciations, given that the irremovable one of each of these types is applied to the remainder after subtracting the irremovable depreciation of the other type as: $(1 - D_2)(1 - D_4)$.

Need clarification regarding the external obsolescence D_5, which, unlike the irremovable physical D_2 and functional D_4 ones, does not tend to accumulate with the age of the asset, and, depending on external economic factors, equally affects the value of industrial assets that are similar functional and structural when other of their ages, as shown by the horizontal line: $RC \cdot (1 - D_5)$ on a schematic graph (Fig. 1).

The durability T of the industrial asset in this schematic graph is harmonized for three independent approaches. With respect to the cost approach, this schematic diagram assumes that the irremovable physical and the functional depreciations accumulate proportionally with the age of the asset t within it durability T.

It is taken into account that the removable depreciation of an industrial asset, i.e. the deferred costs for its maintenance, repair and modernization are eliminated at a certain periodicity. That is, the depreciation of this type is not characterized by accumulation and does not have a noticeable effect on the general shape of the dependence of asset value on it age.

The accuracy of determining the depreciation and value of a non–new asset when estimated by cost approach significantly depends on the correct prediction of the asset durability. The costs as the asset ages is replaced by it depreciation (part of the reconstruction value transferred to accumulated net income at the property complex to which the asset belongs). The market value, which represents the difference between reconstruction costs and accumulated depreciation, finally becomes significantly less than both reconstruction costs and accumulated depreciation.

In practical valuation, the use of the cost approach to determine value is preferable with little depreciation for the brand new and the relatively new industrial assets due to the following reasons.

1. With the age of the industrial asset the information about the costs for its creation is usually lost and there may be the methodological difficulties to find the reconstruction costs or the replacement ones (to produce functional analogue).

2. With the age of the industrial asset commensurate with its longevity, the determination of value by cost approach is to be inaccurate, since the accumulated depreciation is commensurate with the value of the new asset, and finding the value is therefore characterized by the methodological difficulty, considered in mathematics as the “small difference of large values”, which has to be conceptually inaccurate.

3. Depreciation of the industrial asset is manifested not only in a decrease in value, but also in the accumulation of differences of value of initially identical assets. The depreciation can be relatively small with proper maintenance and with sufficient maintenance costs, i.e. with the increase of the asset predictable life. There may also be circumstances of the opposite nature.

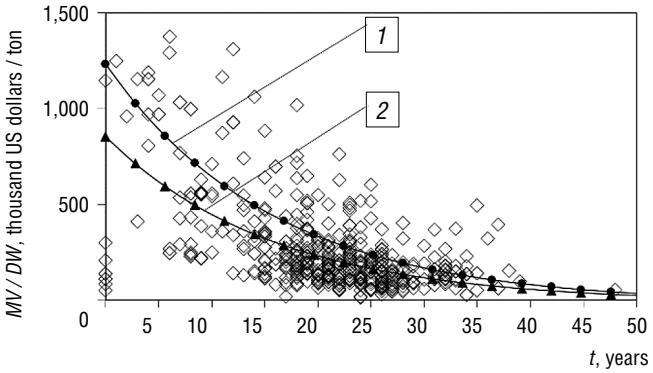

Fig. 2. The regression dependencies of specific value per unit of deadweight (MV/DW) on the age within the durability of universal bulk cargoes ship (the lines for the deadweight DW: 1 — 7,900 ton, 2 — 15,800 ton)

The presented graphs show regression dependence (Fig. 2) corresponding to the application of the comparable sales approach and similarity with analogues in terms of specific value (*MV*/*DW*) per unit of it size (the deadweight *DW*) on the ship age *t* and on the deadweight *DW* of ship for bulk cargoes [3].

The graphs (Fig. 2) show the similarity of the regression dependences of the specific value on the age *t* of ships of the considered classes with the form of the curves of value of industrial asset on it age corresponding to the comparable sales approach indicated on the schematic graph (Fig. 1).

Considering the indicated examples of specific value curves for bulk cargoes carrier ships, the dependence of the specific value of the industrial asset on the age on the schematic graph is shown in accordance with the function:

$$MV_M = DW\left(X \cdot DW^Y e^{Z \cdot DW}\frac{(1+i)^{T-t}-1}{(1+i)^T-1}\right), \quad (2)$$

which is indicated for merchant cargo ships when approximating statistical observations. In this case, in formula (2) the characteristic of the size of ship is used — the deadweight *DW* and the ship age *t*, as well as it durability *T*, and the regression factors are coefficients and degrees: *X*, *Y* and *Z* (that is, the scale effect factor: $XDW^Y e^{Z \cdot DW}$) and the index of discount rate *i*, characterizing the decrease in the value of the industrial asset as it is transferred to accumulation in the property complex of assets, in the system of which this asset is included as an element.

Apparently, similar or close formulas for value estimating by comparable sales approach depending on the age of the industrial asset and on one or another it comparison characteristic, as which the deadweight *DW* was chosen in the example for cargo ship, can be determined for various industrial assets as well in any industrial sectors, taking into account the assumption that value is transferred to investments in the property complex of assets in the form of net income as assets depreciate.

THE FORM OF DEPENDENCE OF VALUE ON AGE WHEN EVALUATING THE INDUSTRIAL ASSET BY INCOME APPROACH

The value of the industrial asset can be found by the income approach by known formula as the present value of the discounted cash

flow of the expected net operation income *NOI* and reversion *Rv*. Assuming the neglect of secondary factors and using the simplifying assumptions, such as the insignificance of the amendment to value of the cash flow at the middle of the billing period, if: $(1+i)^{1/2} \approx 1$, as the smallness of working capital to equip the asset (to install, launch, etc.) required in the form of advance payment and the smallness of other costs that might be required as part of the investment, the formula of industrial asset value determining, as is known [7], is:

$$MV_I = \sum_{n=1}^{T-1} \frac{NOI_n}{(1+i)^{n-1}} + \frac{Rv}{(1+i)^{T-1}}. \quad (3)$$

For the industrial asset, the cash flow is, in principle, stable in the present prices $(NOI_t = NOI)$ due to the sustainability of the characteristics of this asset, and for this reason, net operating income in the present prices does not predictably change over the years, unlike cash flows for property complexes, the value of which, and, accordingly, the cash flow predictably increases by the time as a result of investing profits in fixed assets or of investing other finance in fixed assets, for example, in accordance with a certain plan business project.

Using the methods based on the capitalization of discounted cash flows, the predictable volatility of these flows is not typical for individual industrial assets, which net operating income is predictably sustainable corresponded with their sustainable own characteristics and can only change unpredictably due to external causes, which is the risk factor usually taken into account by the discount rate *j*, which is correlated with the total of risks.

Under the assumption of time independence of net operation income, which is characteristic for individual industrial asset $(NOI_t = NOI)$ the equation of present value of discounted cash flow (3), neglecting the reversion *Rv* in the order of a simplifying assumption, can be represented by the known direct capitalization formula

$$MV_I = NOI/R, \quad (4)$$

where

$$R = i + f = \frac{i+i}{(1+i)^{T-t} - 1}.$$

It can be seen that, in accordance with the income approach, the cause for change of the industrial asset value with its age *t* within the durability *T* is the growth of the compensation fund factor *f*, which is included in the total of the capitalization rate *R*.

According to the graph of capitalization rate *R* dependence on the age of industrial asset within the limits of asset durability (Fig. 3) it is indicated that the denominator in the direct capitalization formula (4) changes noticeably if the asset age *t* approaches durability *T*, which predetermines that form dependence of asset value on it age, determined by income approach, which is performed on the schematic graph (Fig. 1).

If to compare the valuations by income and cost approaches in terms of their adequacy for new or not new industrial assets, then for the valuation of a new asset whose accumulated depreciation is small or zero, the cost approach would be recommended, and the income approach in this case is not entirely logical, since the operating experience of new asset is insufficient and no much income and cost accounting data has been accumulated.

At the same time, for a non-new industrial asset the assessment of value by the income approach would be appropriate, because the economic indexes for the operation of such an asset are likely to be collected in sufficient volume, are available and reliable.

On the other hand, the accumulated depreciation with a large age of the industrial asset in relation to its durability is commensurate with replacement costs, which puts into question

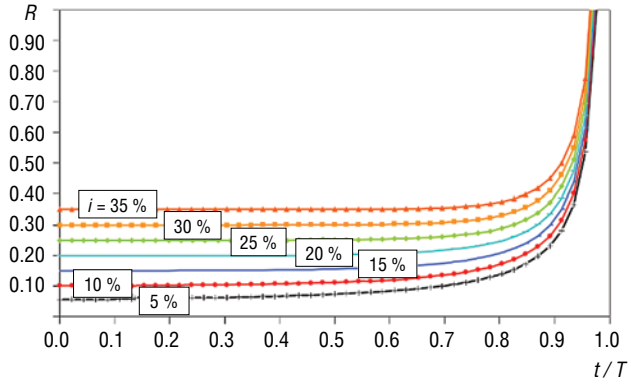

Fig. 3. Dependence of the capitalization rate of net operation income R on discount rate I and on the age of the industrial asset in proportion of the durability (t/T)

the applicability of the cost approach for valuing this asset, and this also contributes to a shift in preferences in favor of using the income approach for valuing not new asset.

THE METHODOLOGICAL INTERRELATION OF COST AND INCOME APPROACHES

There is a methodological similarity and an associated difference between the cost and income approaches when they are used to determine the value of industrial assets. This can be used to determine logically the weighting factors for the harmonizing values found by the cost and income approaches.

Having into account the simplifying assumptions, when opening the brackets, neglecting the multiplication of the indexes of unavoidable physical and functional depreciations: $(D_2 \times D_4)$ and assuming a small influence of the removable depreciation: $(D_1 + D_3)$, reset periodically during maintenance, repair and modernization, on the form of dependence on the age of the industrial asset on its value, estimated by the cost approach: $(1-D_2)\cdot(1-D_4) \approx (1-D_2-D_4)$, the formula of the cost approach (1) of the industrial asset has the form:

$$MV_C \approx MV(0)\cdot(1-D_2-D_4), \quad (5)$$

where $MV(0) = RC\cdot(1-D_5)$ — the value of a new industrial asset, which differs by the external depreciation D_5 (the obsolescence) from the costs of the asset creation, i.e. from the reconstruction costs *RC* of the asset, since the value of the new asset *MV*(0), when the accumulated depreciation is equal to zero, is estimated minus the obsolescence D_5, acting in proportion to the value of similar assets, regardless of their age, including to the value of new ones.

Denoting the analogue of the accumulated irreducible depreciation as the generalized index of part of the asset value: $D(t) = (D_2 + D_4)$ transferred in the form of a cash flow into savings and investing in the property complex of assets to which the valued industrial asset belongs as an element of the system, it is possible to define the dependency of industrial asset value on the age got by the cost approach as

$$MV_C \approx MV(0)\times(1-D(t)). \quad (6)$$

The dependence of asset value on it age *t*, considering the value transfer factor to the cash flow, taking into account that the value of the new industrial asset (at $t = 0$), determined by cost approach is equal the present value of the expected net income and proceeds from the subsequent sale of an asset:

$$MV_I = \sum_{n=1}^{t} \frac{NOI_n}{(1+i)^{n-1}} + \frac{MV(t)}{(1+i)^t},$$

looks like

$$MV_I(t) = MV(0)(1+i)^t - NOI(1+i)^t \sum_{n=1}^{t} \frac{1}{(1+i)^{n-1}}. \quad (7)$$

The comparison of formulas (6) and (7) allows to determine the index of the accumulated depreciation analogue $D(t)$, as:

$$D(t) = 1 - (1+i)^t + i\sum_{n=1}^{t} \frac{1}{(1+i)^{n-t-1}} \quad (8)$$

or, using the direct capitalization formula (4), the index of the accumulated depreciation analogue $D(t)$ one can find as:

$$D(t) = 1 - \frac{1 + 1/\left((1+i)^T - 1\right)}{1 + 1/\left((1+i)^{T-t} - 1\right)}$$

or the accumulated depreciation analogue $D(t)$, that is, the discounted for the valuation day t part of value, transferred in the saved and invested net income, is:

$$D(t) = \frac{1-i}{i+f} = \frac{1-i}{R}. \quad (9)$$

The found index of the accumulated depreciation analogue $D(t)$, that is the part of its value by relative value (relative to the value of the new asset) transferred to the accumulated net income over a period within the age of the industrial asset t, depending on the age of the asset and on it durability T is on the graph (Fig. 4).

The graph shows that the transfer of the value of the industrial asset to the saved and invested net income of the property complex, of which the asset is the element and the subsystem. This saved and invested net income is relatively equal to the index of accumulated depreciation analogue $D(t)$, depended as on the asset age t within it durability T so on the discount rate i.

It should be noted that for the extreme ages of industrial asset within the limits of it durability there is also the correspondence of income and cost approaches' results of value estimate with one got by the comparable sales approach.

1. Of the result of value estimate got by a cost approach — at zero or small age, i.e. for a new industrial asset whose accumulated depreciation is insignificant. This may give ground for equal preferences of the applicability of cost and comparable sales approaches, given the similarity of these approaches when valuing a new asset, taking into account the low applicability of the income approach in the absence of data.

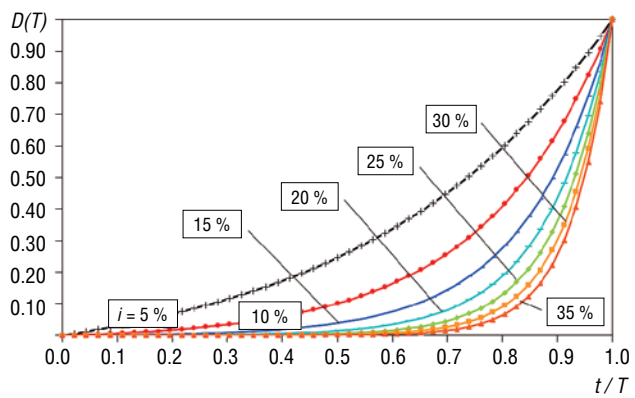

Fig. 4. The dependence of the accumulated depreciation analogue D(t) of the industrial asset on the ratio of age and durability of the asset (t/T) and on the discount rate i

2. Of the result of value estimate found by income approach — with the greatest age of the asset within the durability range, the income from which can be obtained by selling the asset, for example, at a residual liquidation or other value, found, in particular, by a comparable sales approach. This indicates the methodological similarity of income and comparable sales approaches for an asset that is close to its ultimate life, the use of a cost approach for valuation, which is not preferred due to the comparability of the replacement cost and accumulated depreciation.

DIMENSIONAL REDUCTION OF THE PROBLEM OF WEIGHT FACTORS FINDING CONSIDERING THE METHODOLOGICAL INTERDEPENDENCE OF COST AND INCOME APPROACHES

The harmonization of industrial asset values, found by independent approaches: the cost one MV_C, the income MV_I and the comparable sales MV_M with use of the weight factors (a_C, a_I and a_M), is being done as:

$$MV = MV_C \times a_C + MV_I \times a_I + MV_M \times a_M,$$

where the total of the weight factors is equal to one:

$$a_C + a_I + a_M = 1.0. \quad (10)$$

As it is indicated above, with minimal depreciation and with a low age of the asset, i.e. the cost approach is preferable for determining of the asset value under the assumptions that: $t \approx 0$, $D(t) \approx 0$ and $MV(t) \approx MV(0)$, and with the maximum accumulated depreciation the use of income approach is preferable an its turn, i.e. under the assumptions that: $t \approx T$, $D(t) \approx 1$ and $MV(t) \approx 0$ that is when most of the initial value $MV(0)$ of the asset was transferred to saved and invested net income of the property complex, to which the valuated asset belongs as an element of the system.

The weight factors for the values of industrial asset, found by income a_I and cost a_C approaches, considering the specified assumptions of preferred choice with respect to each of these approaches can be found using the index of accumulated depreciation analogue $D(t)$.

Thus, it is possible at final harmonizing of the values: MV_C, MV_I and MV_M to transform the issue of determining of weight factors, which will be reduced to an expert determination of the weight factor a_M of the account of asset value, found by comparable sales approach MV_M.

Deducting the weight factor a_M, considering at final harmonizing of value MV_M, found by the comparable sales approach, the dependence of the weight factor a_I for the account of the final harmonizing of found by cost approach value estimate MV_I, corresponded with the discounted for the valuation day t part of value, which is the accumulated depreciation analogue $D(t)$, transferred in the saved and invested net income, and the dependence of the weight factor a_C for the account of value MV_C, found by the cost approach, as remainder of one deducting the factors: a_I and a_M look like (Fig. 5 for the discount rate value 20 %):

$$a_I = (1 - a_M) \cdot D(t)$$

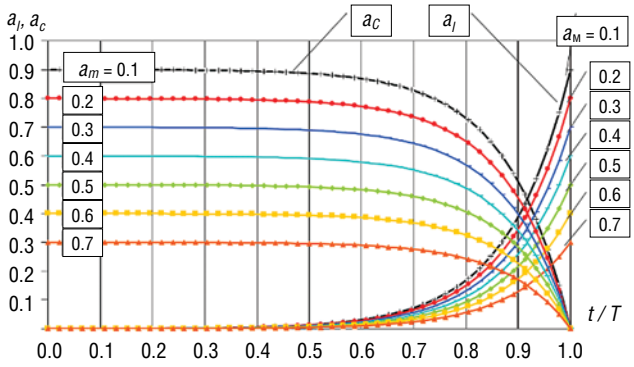

Fig. 5. The dependences of weight factors, used in the final harmonizing of the values: the factor a_C for the account of value MV_C found by the cost approach, and the factor a_I for the value MV_I, found by income approach, on the industrial asset age (t/T) in relation to its durability, as well as on of the weight factor previously found a_M for the value MV_M, determined by comparable sales approach

and

$$a_C = (1 - a_M)\left(\left(1 - D(t)\right)\right). \quad (11)$$

When using the weight factors: a_I and a_C, found by the formulas (11), in the dependence on expert weight factor a_M, used for account at final harmonizing of value MV_M, determined by comparable sales approach, and in the dependence on the accumulated depreciation analogue $D(t)$ of industrial asset the coordination (10) of the asset value looks like:

$$MV = MV_C\left(1 - a_M\right)\left(1 - D(t)\right) + MV_I(1 - a_M)D(t) + MV_M \cdot a_M. \quad (12)$$

The resulting dependencies of industrial asset harmonized value, found by the independent approaches on the asset age (t/T) on expert assigned weight factor well a_M, used for account of the value, found by comparable sales approach MV_M, are indicated on the graphs (Fig. 6) for the discount rate value 20 %.

Analysis of results of matching the value of industrial asset values found by the cost, the income and the comparable sales approaches: MV_C, MV_I and MV_M, indicates that the increase of weight

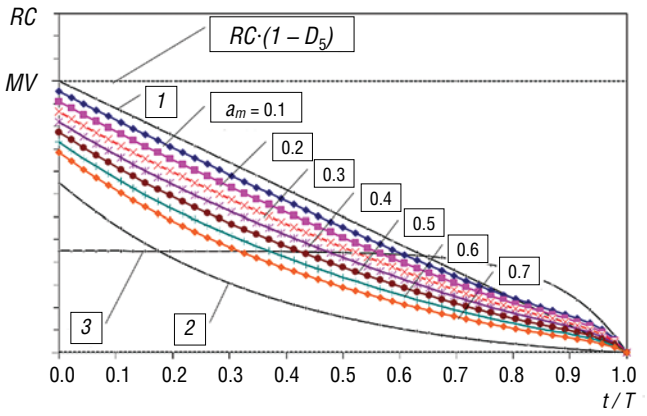

Fig. 6. The dependences of the harmonized value of industrial asset; the dependences on the age of the industrial asset of it values, found by independent approaches: 1 — the cost approach; 2 — the comparable sales; 3 — the income one on the asset age (t/T) in relation to its durability, as well as on the weight factor previously found a_M for the value MV_M, determined by comparable sales approach

factor a_M, used for the account of value MV_M, got by comparable sales approach, could be characterized by the total value decrease.

With the increase of age t within it durability T of the industrial asset the depreciation of the asset increases as well as the accumulation of a part of its value, transferred to the net income of the property complex, the subsystem and element of which this asset is, in the process of value matching in accordance with the formulas (10)–(12), the preliminary for the new asset value estimate MV_C, found by cost approach, for which: $t \approx 0$, $D(t) \approx 0$ and $MV(t) \approx MV(0)$, gradually in a certain methodological sequence is replaced by the value MV_I, found by income approach.

And with the maximum accumulated depreciation of an industrial asset, which is characterized by the indicators: $t \approx T$, $D(t) \approx 1$ and $MV(t) \approx 0$, the preferred result in the final matching of values is the result, got by income approach MV_I.

The final harmonizing of the value estimates: MV_I and MV_C, got by income and cost approaches proportional to $D(t)$ and $(1 - D(t))$ of values, acts in the rest after expert accounting of factor a_M of industrial asset value estimate by comparable sales approach MV_M.

CONCLUSIONS AND RECOMMENDATIONS

1. The concept of industrial asset, which serves as the element of a complex system, is associated with its functional characteristics, such as: the assignment, type of vehicle or machine, assignment of an equipment object, one or another intellectual product, and etc. Unlike an industrial asset, a complex object, for example, an integral property complex of the acting company, which includes this asset, enters as an element of the system, which can be characterized not by the functional assignment, as industrial assets included in it, but by the type of the economic activity.

2. The industrial asset has a limited economic durability and by the time its value in the form of income is transferred to accumulations in the property complex in which the asset is included, that is the asset value as the annual net income is invested in the property complex. Estimation error and discrepancy found by the independent approaches of values can be the indicators of the valuation quality. When determining the relative valuation error of value estimate the comparison base is used, which somehow or other remains unchanged or sustainable during the systemic cycle of the asset: creation, installation, equipping and launching, productive use, maintenance, decommissioning and disposal.

3. Methodological discrepancies in determining the value of the industrial asset by independent approaches are associated with possible inconsistencies of normative concept of the value according to federal law and according to valuation standards, on one hand, and the value methodological definition as the result of harmonized use of independent valuation approaches according to standards as well. This discrepancy between the normative concept and methodological definition of value emerges simultaneously with the question of the correspondence of the independent valuation approaches among themselves within the specified methodological definition.

4. To reduce the dimension of the problem of the weight factors finding to harmonize the estimates by independent approaches one can use the methodological similarity of the estimate by the cost and the income approaches. As an economic analogue of the accumulated depreciation of the industrial asset the index of the part of value of the asset is used, and this part is transferred in the form of net operation income accumulation to investing in the property complex of industrial assets, to which the valuated

one belongs as an element of system. For the final harmonizing of value estimates in dependence on the age of industrial asset within its durability, the weight factor of the results of valuation by income approach is commensurate with the accumulated depreciation analogue, and for harmonizing of the result got by cost approach the factor proportional to the deducting residue of the accumulated depreciation.

5. The ratio of the weight factors for the results of valuation by cost and income approaches is a function of analogue of the accumulated depreciation, in turn depending on the age of the industrial asset, on its durability and on the risk and efficiency index characterizing the property complex to which the industrial asset being valued belongs as an element (the subsystem of system), and the sum of these two weight factors for the evaluation by cost and income approaches corresponds to the remainder of one after subtracting the expertly assigned weight factor adopted for the comparable sales approach. Having into account the recommendations under consideration, the task of determining the weight factors with the final harmonizing of value estimates, found by the independent approaches, can be reduced to an alternative choice for the industrial asset: finding the value for a serial asset (or in a developed market) by a comparable sales approach, which is quite common, or under other market conditions finding the value estimates by cost and income approaches, taking into account the distribution of the weight factors in accordance with the recommendations, considering the depreciation analogue of industrial asset (the asset value transfer as it net income to property complex, to which this asset belongs as the subsystem) according to specified formulas (11).

6. The dimension of the problem of choosing two the weight factors is reduced to match found by income, cost and comparable sales approaches of three of the values of industrial asset, which is included as an element in the overall system, when to match the values obtained by cost and income approaches there is the dependence of their weight factors on the accumulated depreciation analogue (the age and durability of the asset, as well as on the level of efficiency and risks of the system in which the industrial asset is included as the subsystem, for example, on found index of the discount rate characteristic of the property complex).

Given that one of the three weight factors is the remainder of one after subtracting of two of they, then when valuating by three approaches it is recommended the expert determination of the weight factor for value found by comparable sales approach, and the second weight factor and a third one (remainder of one after subtracting two factors) one can find by specified equation.

7. Besides considered methodological correspondence of the cost and income approaches, when evaluating an industrial asset, one can also see these approaches pair correspondence with the comparable sales approach under the appropriate conditions:

- with the result of value estimate, found by the cost approach at zero or small age, i.e. for a new industrial asset, the accumulated depreciation of which is insignificant, when the determination of accumulated depreciation is not required, and the value of the asset found by the cost approach is equal to the replacement cost, determined, in particular, by comparable sales approach with insufficient data for use of the income approach (not enough income experience for new asset);
- with the result got by income approach — with the greatest age of the asset within the limits of durability, the income from which can be obtained by selling the asset, for example, at a residual liquidation or other value, found, in particular, by the comparable sales approach, when the use of the cost approach for valuation is not enough accurate due to the proportionality of the accumulated depreciation and the replacement cost for a non-new industrial asset.

8. In practical tasks of evaluating of serial standard assets, as is known, it makes sense to determine value by methods of comparable sales approach, and for those assets for which the use of the comparable sales approach is difficult, for example, due to the lack of market analogues, usually valuation uses methods of cost and income approaches. In both options, at the stage of choosing the approaches for valuation, it is possible to avoid or to minimize the further problem of expert finding the weight factors — both when assessing only by comparable sales approach, which is logical for serial standard assets, when the weight factor for the value estimate by this approach corresponds to one, and for other assets when valuated by cost and income approaches and using the weight factors as a function of the age of the industrial asset, of it durability and of the efficiency index of the system in which the industrial asset is included as the subsystem. In the second case, the task does not emerge of expert finding of the weight factor for the evaluation result by comparable sales approach.

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Системные причины погрешности и расхождений при оценке стоимости промышленного актива независимыми подходами и рекомендации для согласования результатов оценки

Оценка стоимости промышленных активов производится для принятия решений при формировании комплексов этих активов в составе бизнесов действующих предприятий, а также при создании самих активов, при их приобретении, при списании на утилизацию и в иных обстоятельствах. Погрешность оценки и расхождение результатов, найденных независимыми подходами, могут выступать показателями качества оценки. База определяемой погрешности оценки стоимости должна в зависимости от возраста промышленного актива и его накапливаемого износа корректироваться, поскольку непосредственно стоимость актива в пределах его долговечности с возрастом снижается до нуля и поэтому не может служить базой относительной погрешности оценки. Причинами несоответствия стоимости промышленного актива ее значениям, найденным независимыми подходами, являются как приближенность исходных данных, которыми при оценке заменяются характеристики общей системы, в которую оцениваемый актив входит как подсистема, так и методологические различия стоимости как нормативного понятия и стоимости как совокупности методов ее нахождения с использованием независимых подходов. Для согласования результатов, найденных каждым независимым подходом, производится анализ их соответствия адекватным методологическим принципам оценки и свойствам промышленного актива. С учетом свойства накопления износа и ограниченной долговечности актива распределение стоимостных значений, полученных затратным и доходным подходами, при согласовании этих значений может быть рационализировано с использованием предложенного метода. После экспертного определения весового коэффициента для учета результата, полученного сравнительным подходом, при итоговом согласовании вклады результатов оценки независимыми затратным и доходным подходами рассчитываются соразмерно переносу накапливаемого чистого дохода в стоимость имущественного комплекса, к которому оцениваемый промышленный актив принадлежит как элемент системы.

Ключевые слова: *промышленный актив, имущественный комплекс, назначение актива, долговечность актива, изменение стоимости, независимый подход, имущественный комплекс, элемент комплекса, системная связь, погрешность данных, понятие стоимости, определение стоимости, соответствие определений, согласование стоимости, перенос стоимости, экономический износ*

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For citation: Voyloshnikov M.V., Kulakov K.Yu., Krivets V.V. Systemic causes of discrepancies in the valuation of an industrial asset by the independent approaches and the recommendations for the valuation results harmonizing. *Real estate: economics, management*. 2022; 4:27-36.

Для цитирования: *Войлошников М.В., Кулаков К.Ю., Кривец В.В.* Systemic causes of discrepancies in the valuation of an industrial asset by the independent approaches and the recommendations for the valuation results harmonizing // Недвижимость: экономика, управление. 2022. № 4. С. 27–36.