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USING TERRAIN LASER SCANNING FOR DETERMINING REAL ESTATE PHYSICAL DETERIORATION

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The purpose of the study. The problem of applying terrain laser scanning method (TLS) is current, when it is used to determine real estate and construction physical deterioration of industrial areas and cultural heritage objects. The quality of laser scanning gives the possibility to develop intensively application of TLS for determining building deformation and engineering structures and physical deterioration of their structural components, inside and outside the object. Today the necessity to apply new modern methods has appeared in order to make an objective valuation and thus, to set its market value. **Methodology**. The methodology is based on the necessity of applying the terrain laser scanning method for determining real estate physical deterioration. While assessing valuating the real estate the main criteria is its physical deterioration for determining building and structure value which is considered as its validity loss and as a result its value loss for any reason [Kharryson H., 1994; Ekkert K., 1997]. The main factors that effect the accuracy and quality of laser scanning are considered to be the accuracy of the device (calibration); scanning conditions (weather conditions); scanning object properties (reflectivity); scanning geometry; previous processing of scanned material (Schultz R., 2010). **The results**. The importance of terrain laser scanning for calculation of building and structure physical deterioration has been learnt during application. The result has been the basis for the development of a new methodology of real estate valuation. Today the value of building component physical deterioration is determined by visual observation with the help of the simplest devices (plumb, linear, hammer, etc.). The value of physical depreciation of separate structures, and their technical equipment or their parts is determined by comparing of the existing features of physical deterioration with those which have been found during the observation [Kirichek Yu., 2016]. TLS application gives the possibility to set accurately structural parts of the damaged real estate. **Scientific innovation**. The research has been done based on the possibility of using digital laser scanning for determining the real estate physical deterioration. The necessity of using terrain scanning method in order to improve the methodology of real estate's valuation and determination its physical depreciation has been stated in the article. This method gives the possibility to avoid appraiser's subjectivity while calculating, and in accordance with "legal weak-points" of the got results of real estate market value. It has been defined that regulatory methodological documents of real estate physical deterioration are out of date and do not coincide with the real estate market requirements. That is why they need to be improved. **Its practical significance.** Using TLS for real estate valuation is of a great economic efficiency. It reduces the cost for determining the geometric object characteristics tenfold compared to traditional geodetic methods. Appraisers are recommended in their work to use pulse and phase laser scanners for determining real estate physical deterioration. Terrain laser scanning gives the possibility to get detailed structure of the real estate.

Key words: physical deterioration, terrain laser scanning, valuation, real estate market value, buildings and constructions.

Introduction

There is a fundamental difference between the meaning of depreciation as market value reduction and its meaning as an accountant of its reduction based on standard of depreciation rate. Thus, valuating deterioration always reflects the market reaction to the object's aging and accountant reduction is a standard value of reverse deterioration value. Valuating deterioration does not correspond to the age of the real estate, and accounting reduction is always correlative with it.

The simplest concept of deterioration, especially with short existing separate components has a linear approach. The subject of this concept is that permanent annual percentage (which is equal to adopted annual deterioration) is used for reducing

the cost in such way that its functional term is equal to 100 % of the initial object value. This linear approach is simple and easy, but it does not fully reflect the reality of the most cases. The time factor is not the only factor effecting the deterioration. Thus, it prevents determination of the exploitation value. Time period has less impact on additional object destruction itself if real estate physical and functional conditions are quite good.

As the object's age is a critical factor thus, the best approach to value real estate physical deterioration is to combine object state and age. For example, heating, ventilation and air conditioning under the pressure of hard usage in the condition of hot or humid climate can deteriorated quickly thus reducing its functional time. At the same time components of construction such as pit, foundation and cement exterior walls can be deteriorated quite slowly. These durable components of construction are often the main parts of the total real estate value. When they are preserved it means that they will extend their functional time. Physical deterioration can not be regarded as the direct deduction out of the recreated value. The periodical maintenance and object repairing may make slower or even completely delay the deterioration. Another approach to determination such has been called mid functional term theory. This approach takes into account that most of the buildings have been partly ruined during the first few years. When it is obvious that the buildings are no longer new, despite on the fact that they are kept in good condition, the cost service is increasing, rent payment is lowering and buildings are destroyed more quickly. They will be at the so-called mid functional term period in a few years during which, if the buildings are in stable condition and are served properly the deterioration remains unchanged. The theory of mid functional term does not take into account the fact that the average building expenditures are arising for saving their exterior. But ages of building components may be out of date at any period of their functional term.

These concepts are the basis for the third theory which is called the concept of extended functional time. The starting point of the concept is the hypothesis that buildings are aging nearly in the same way as a man and the older he is the more is expected of their functional term. This concept considers that the building is in its best condition up to the mid functional term and the rapid deterioration of building characteristics begins further. But defects of the building can reduce the effective object age and extend its remaining functional term. This renewal process that is repeated periodically prevents rapid aging determined by aging scale. It diminishes the rate of deterioration because building components are renewed. This nonlinear approach explains the large current value and lower deterioration rate at the beginning of functional term in comparison with the further period when real estate exploitation can accelerate deterioration. [Perovych L., Hubar Yu., 2016; Kirichek Yu., 2016; Kharryson H., 1994; Ekkert K., 1997].

The purpose

With the development of modern methods of terrain laser scanning (TLS) of real estate, industrial areas and cultural heritage objects the problem of applying these methods to determine the building and construction physical deterioration has become urgent. The quality of laser scanning has given the possibility to rapid development of applying TLS for monitoring landslides and deformations, territory management, etc. [Dorozhynskii O., 2010, 2014]. Today there is a necessity of implementing new modern methods in order to avoid appraiser's subjectivity and thus, to obtain real market value. The possibility of laser scanning is constantly extending. Deciding different scientific tasks by using laser scanning is important for getting maximum accuracy.

Methodology

The complex real estate deterioration means dimension of land recreation value (replacement) when it is not properly exploited (physical deterioration); with the appearance of new modern and effective improvements (functional deterioration); under the influence of external changes which are basis for real estate market in general (external deterioration).

Thus, the cumulative deterioration of land is calculated using the following formula [Drapikovskii O., 2015]:

$$I = 1 - (1 - I_{phys}) \cdot (1 - I_{func}) \cdot (1 - I_{ext}), \quad (1)$$

where I is cumulative deterioration coefficient; I_{phys} is physical deterioration coefficient; I_{func} is functional deterioration coefficient, and I_{ext} is external deterioration coefficient.

While determining the cumulative deterioration of land recreation it must be taken into account that for buildings and constructions located in areas with increasing attractiveness, the market value is the result of simultaneous influence of the opposite processes (negative is physical and functional deterioration and positive is external recreation). Thus, the loss of object value because of physical and functional aging and its value increasing based on external factors. Thus, taking into account the valuation of cumulative deterioration plays an important role in setting the real estate market value.

Physical deterioration (deterioration) is a loss of recreating value due to various physical damages of the building structure, equipment and decoration. The value of physical deterioration is characterized by technical and exploiting building and construction indexes which have become worse. The project one is determined by the correlation of necessary spenders for their repairing to the real estate recreation value.

The exact percentage of the physical deterioration value within taken interval is determined based on the following considerations:

- if the part has all the features of physical deterioration for the set interval this value is considered to be and equal to the upper interval margin;
- if in the part only one of several features of physical deterioration is found this value is considered to be equal to the lower interval margin;
- if physical deterioration must be determined only by one feature (or incomplete set of features) it is calculated by the way of interpolation depending on its size or nature of its existing defects.

The following methods for determining physical deterioration of buildings and constructions are practically used: enlarging scale; determining physical deterioration of components; involving technicians.

The method of determining physical deterioration of components is implemented in VSN 53-86 “Regulation of building physical deterioration value” it has been the basis for approving “Regulation of residential building physical deterioration value “KDP-2041-12 Ukraine 226-93 and later it became the basis for processing Ukrainian utility standard “Regulation of residential building physical deterioration value” SOU utilities 75.11-35077234.0015-2009. Appraisers usually use approximate valuation scale of physical deterioration (Table 1).

Table 1

Approximate Valuation Scale of Building Component Deterioration

Physical deterioration, %	Valuation of physical condition	General characteristics of physical condition
0–20	Good	There is no deformation but there are some defects which do not effect exploitation of the component of the building and they can be taken away during with repair.
21–40	Satisfactory	Components of building are valid but need repairing which is the most effective at this stage.
41–60	Unsatisfactory	Functional components of the building are possible to exploit only in the condition of their repair.
61–80	Emergency	The bearing structural components of the building are in the state of emergency and their operating features are limited and they can be exploited only after the done secure measures or complete replacement of these components.
81–100	Invalidity	Components of the building are ruined. When its deterioration is 100 % it is completely destroyed.

Table 2

Standard Valuation Requirements of Brick Wall Physical Deterioration

Features of deterioration	Quantitative valuation	Physical deterioration, %	Measures required
Some cracks and potholes	The width of cracks is up to 1mm	0–10	Cementing of cracks and potholes
The depth of the cracks and falling plaster in some places, mortar weathering out of joints	The width of cracks is up to 2 mm, its depth is up to 1/3 of the wall thickness, destroying joint up to 1 cm of the depth and the destroying area is up to 10 %	11–20	Plaster repairing, joint expansion or cleaning exterior
Falling of wall plaster, cornice and structural frames, mortar weathering out of the joints	The depth of the joint destruction is up to 2 cm at the area of 30 %. The width of the cracks is more than 2 mm	21–30	Plaster repairing and brickwork, joint cementing, external cleaning, repairing of cornices and structural frames
Expended plaster defects; mortar weathering; loosing of bricks and loss of separate bricks	The depth of joint destruction is up to 4 cm of about 50 % of the area	31–40	Repairing of damaged wall sections, cornices and structural frames
Outlet cracks frame under window space, brick falling, small vertical displacement, deflection	Indoors vertical displacement is not more than 1/200 of a height, wall deflection is up to 1/200 of deformative area length	41–50	Fastening walls with belts and joists, fastening piers
Loss of brick laying, different sediment, expanding outlet cracks, weakening, significant wall distortions	Deflection with deformation over 1/200 of the deformative area length	51–60	Brick laying of 50 % of the walls, fastening and mounting the remaining parts of the walls
Partial destroying of brick laying	–	61–70	Entire brick laying of the walls

Standard of Ukrainian utilities "Regulation of residential building physical deterioration value" gives information about physical deterioration value for various buildings and constructions depending on their technical state characteristics (aging, defects, damages) of separate structures such as: foundations, walls, ceilings, floors, window and doorways, electrical network and plumbing. Standard valuation requirements of brick wall physical deterioration are shown at Table 2.

The part of separate structural components and the system of engineering equipment for buildings and constructions is used for average deterioration calculation.

Thus, the physical deterioration value is determined by the formula [Perovych L., Hubar Yu., 2016; Kirichek Yu., 2016]:

$$F_c = \sum_{i=1}^{n} F_i \cdot \frac{P_i}{P_c} \ , \qquad (2)$$

where F_c is the physical deterioration value of the building component, %; F_i is physical deterioration value of separate parts of the component %; P_i is the size and the cost of the component part, m, m^2, m^3, %, UAH; P_c is the size and the cost of the entire component, m, m^2, m^3, %, UAH; and n is the number of parts the component has been divided into.

The average deterioration value is calculated by the formula [Perovych L., Hubar Yu., 2016; Kirichek Yu., 2016] based on data of determined separate construction deterioration and their parts in the entire building construction.

$$F_b = \sum_{i=1}^{n} F_{eq} \cdot \frac{l_i}{100} , \qquad (3)$$

where F_b is building physical deterioration value, %; F_{eq} is physical deterioration value of sepa-

rate parts, technical equipment, %; l_i is the density of components in the recreating building value, %; *n* is the number of separate building components.

The scheme of real estate functional time period is shown at Fig. 1 [Perovych L., Hubar Yu., 2016].

The period of economic building existence is a time-period during which the building can be used for profit. This is the full period of time during which recreations increase real estate value. Recreation comes to the end of their economical existence when their part in ageing area is zero because of its ageing.

The period of physical building existence is the time period during which a building exists and is valid for living or functioning there in. As 90 % of constructions has been built hundreds of years ago, and they are still existing it is almost impossible to predict their expected lifespan. Using tables for calculating the entire physical existence of different types of buildings one must be very attentive, because for an appraiser they have limited value [Perovych L., Hubar Yu., 2016; Kirichek Yu., 2016; Drapikovskii O., 2015].

Effective period is based on the upraising of the building exterior which takes into consideration its condition, design and economic factors effecting its value. For example, if the building condition is like a 13-year-old building, it must be valued like a 13-year old one (with the effective term of 13 years), even if the building has been 10 or 20 years old. Its value must be mentioned in the building chronology if it is known, but it can usually be ignored when calculating building value.

The remaining period of economic building existence is the period from the valuation date until its end and this must be calculated by an appraiser. It cannot be considered as timely real estate deterioration and real estate destruction. Such factors as frequent repairing, modernization and equipping will increase real estate existence while the lack of these factors decrease its existence. During the real estate valuation to determine the physical real estate deterioration the method of determining existent period is used more often which is calculated by the formula [Perovych L., Hubar Yu., 2016]:

$$I_{phys} = \frac{BC}{PEBE}, \quad (4)$$

where I_{phys} is building physical deterioration; BC is building chronology; $PEBE$ is the period of economic building existence.

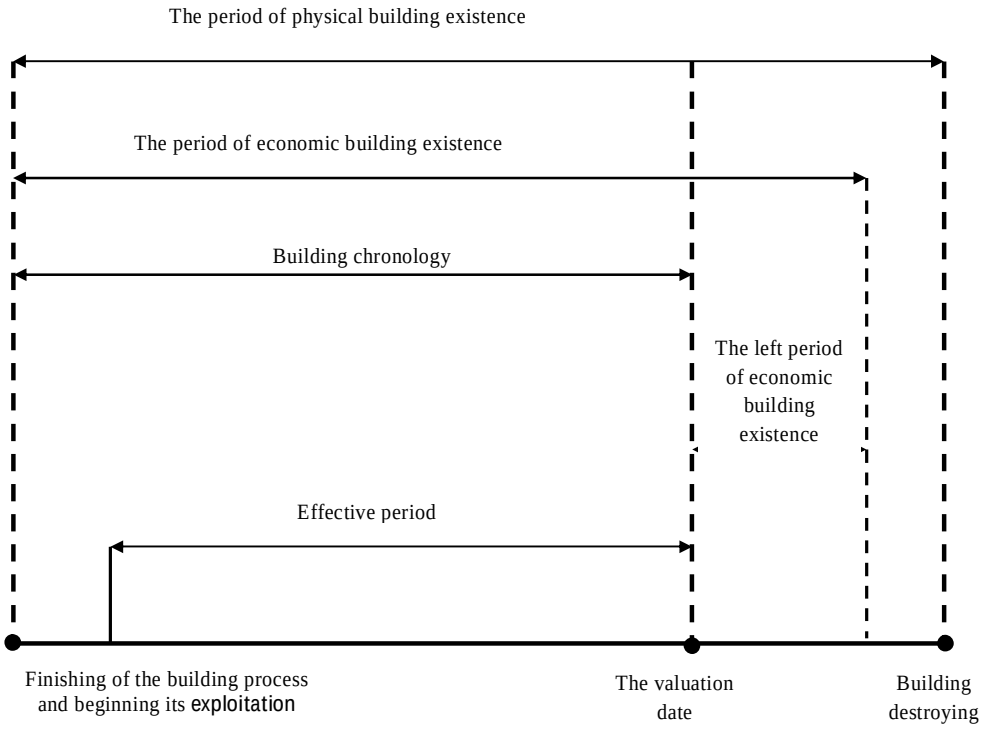

Fig. 1. The period of real estate existence

The advantage of the equation (4) is its simplicity. However, it has some disadvantages:

- linear nature of dependence which does not reflect the real (non-linear) nature of physical real estate value reduction in time;
- achieving absolute physical deterioration of equal chronological periods for economic building existence. This value is exceeding when $PEBE < BC$.

Modern approaches to the analysis of physical building and construction deterioration provide its dividing into remedial and remediless ones.

Remedial physical deterioration (delaying repairing) means that it is accumulated frame deterioration and decorations, building equipment which appear under the impact of poor maintenance and delayed repair. Remedial deterioration is such kind of deterioration when the recreating cost is less than the effect got out of the recreation. The remedial physical deterioration is understood as the value lost under the impact of possible repairing cost for the damaged building constructions and building components. It is assumed that the constructions and the building components will be completely restored to the standards of expectation or completely replaced.

Remediless physical deterioration is a natural process of ageing of building materials, constructions, engineering equipment. This deterioration is calculated as the remainder value of constructions and components (excluding remedial physical deterioration) proportionally to the correlation of actual and expected terms of construction and component existence. If the actual period of any component of the building existence exceeds the expected period of its existence then than certain component is 100 %. Remediless physical deterioration is calculated separately basing on different structural components, and it is monetarized by determining the physical age of the component divided by the period of its physical existence and by multiplying the got value by the value of creating component. For further calculations, the market object value, the got remedial and remediless physical deterioration values are summarized [Jack P. Friedman, Jack C. Harris, J. Bruce Lindeman. 2012; McKenzie M. Betts R., 1992; Ventolo W., Wiiliams M., 2005].

Thus, as stated above, it is necessary to improve the procedures and methods for determining the physical building deterioration. Taken into account the standard subjectivity in determining the physical building and construction deterioration and in order to avoid this, it has been suggested to apply terrain laser scanning method for improving quantitative and qualitative physical state value of the structural components of the studying object. As the result, it gives the possibility to avoid “legal weak-points” of the results of real estate market value by the appraisal.

Using terrain laser scanning for real estate valuation is suggested in this article. Thus, it helps to avoid appraiser’s subjectivity. Applying of TLS give the possibility to accurately assess damages of structural components of the real estate.

Laser scanning is a method of creating a digital object model with the help of laser (scanning) in the form of a dense point network defined by spatial coordinates. Terrain Laser Scanner (TLS) is a device that measures the distance to the object point and two angles: horizontal and vertical. Three resulted values obtained in such a way give the possibility to calculate the spatial point coordinates reflected by the laser ray. Laser scanner significantly affects any surveying, because so many point coordinates can be got manually in a few minutes that it cannot be got by any other method.

Modern methods of computer information processing is based on the creation of digital object models (DOM), digital terrain models (DTM) and digital relief models (DRM), are in priority of a number of scientific and economic tasks. Deciding a large number of applying tasks requires getting information about the area in digital form, such as interactive methods of projecting engineering constructions, analysis of spatial data, terrain management etc. [Dorozhynskii O., 2014].

In the article by Miller P., 2008 and Dorozhynskii O., 2014 it is stated that the important component of the laser system is software. It fulfils the field work and device monitoring, optimizing the information amount for storage and it also performs visualization of “images”, construction of 3D-models, data analysis, their processing and their presentation result in standard formats which are

accessible to other systems. The positive features of laser scanner are sure to be:

- there is no need for a reflective prism or mirror on the object surface unlike an electronic tachometer;
- high velocity of surface scanning in the range from 5.000 to 1.000.000 measurements per second;
- high degree of field work automation, at almost minimum operator's activity;
- distance studying of the object situated in a hard access for a human;
- high point density on the object surface (thousands or hundreds of thousands of points);

Technological scheme of TLS for determining physical deterioration has the following steps:

- work projecting (the calculation and the valuation of the expected scanning accuracy is done);
- field work (scanning station and securing marked points setting at the object);
- object scanning;
- office work (calculation of the station coordinates and "marked" points, processing scanning results, getting the final results);
- the analysis of the got results and calculation of physical building deterioration.

Thanks to the high level of automation and work productivity providing the accuracy in creating spatial object models the terrain laser scanning has been used for applying in different branches. It is applied for deformation and landslide monitoring, mine surveying, topography and territory object management, civil and industrial building, cultural heritage objects etc. The exact full-scale measurement can be done by using TLS. Graphical information about the object valuation can be considered effectively by applying TLS too [Dorozhynskii O., 2014; Miller P., 2008].

The studying concerning conducting frontal plans of architecture constructions by digital terrain scanning and laser scanning has been considered in the article [Glotov V., Resin K., 2008]. It has been stated that the set of points obtained by using laser scanning gives the possibility to detect the errors connected with survey, to learn and consider the distortion of the made images (distortion, error, orientation components, etc.). The accuracy of the set coordinates of the construction meets the demands of accurate measurements of architectural monuments.

Thus, it is adopted that using TLS for the exact determining of areas and volumes of apartments, buildings, constructions and other real estate objects can be done. In addition, TLS gives the possibility to set quantitative and qualitative characteristics of the object components more exactly. It gives the possibility to avoid appraiser's subjectivity while determining the real estate physical deterioration. As the result, it is suggested to determine the real estate physical deterioration by using pulse and phase laser scanners.

Accuracy of the data is the most important fact for deciding various scientific tasks with the help of terrain laser scanning. It is a well-known fact that the accuracy of laser scanning depends on a number of factors. One of them is the laser scanner accuracy. Modern scanner producers do not usually point out the accuracy of the coordinates set with the help of laser scanner. The most common characteristics set in the instruction are the accuracy of distant measurement and the accuracy of the point coordinates for a certain distance. The working principle of laser scanner, based on setting not a single point but a cloud of points and makes the process of calibration difficult. It is difficult to calibrate terrain laser scanners because unlike camera, it is too complicated to create a physical model of the systematic errors [Schultz R., 2011, 2012].

The first large-scale studies of the scan accuracy has been done in Germany at the Institute for Spatial Information and Measurement Technology (in the town of Mainz) in 2002–2005. The test object has been the steps with the surface of 3,5×5 m in size. The marked points have had spherical surface and have been set on the device, their coordinates had been known. The studying object has been scanned out of three stations at the distance of 15 m. To learn its resolution a box has been made 30×30 cm in size as a measuring unit. The ray width was 30 cm at the margin of the box. Scanning was carried out at a distance of 6 m and 22 m. The test in the form of two painted plates placed at different distance from the scanner was applied to learn the effect of ray reflection at the margin of two set surfaces. The main studying results are shown at Table 3 and 4.

Table 3

Linear Displacement Caused by Angular Errors at Vertical and Horizontal Planes

№	Scanner	Vertical displacement, mm	Horizontal displacement, mm	Maximum difference, mm
1	Callidus-1	5.6	4.3	12.2
2	Callidus-2	9.9	2.5	18.3
3	Cyrax 2500-1	0.8	0.8	1.6
4	Cyrax 2500-2	0.5	0.5	1.1
5	Mensi S25	3.8	3.4	9.2
6	Mensi GS100	1.9	2.3	3.3
7	Mensi GS200	4.7	2.2	8.3
8	Riegl LMS Z210	10.2	16.8	27.1
9	Riegl LMS Z420i	1.7	2.1	4.1
10	Riegl LMS 25HA	2.5	3.9	6.5
11	Zoller+Fr. Imager 5003	2.9	7.5	11.1

Table 4

Linear Measurement Valuation for Different Types of Scanners

№	Scanner	Accuracy of the segment at the distance, mm		Maximum difference, mm
		Up to 10 m	From 10 to 50 m	
1	Callidus-1	1.5	–	2.6
2	Callidus-2	2.8	–	5.9
3	Cyrax 2500-1	0.6	1.1	2.3
4	Cyrax 2500-2	0.4	0.5	0.9
5	Mensi S25	1.4	4.6	7.7
6	Mensi GS100	2.6	2.0	8.2
7	Riegl LMS Z210	19.7	–	40.4
8	Riegl LMS Z420i	2.6	2.7	5.9
9	Zoller+Fr. Imager 5003	1.6	0.7	12.3

The accuracy of linear measurements is set based on linear displacement 14 segments are used at a taken distance of 10 m; 14 segments are used at a taken distance of 10–50 m. The data are shown at Table. 4.

The facts learnt above show that used methods of terrain laser scanner give the possibility to value the quality and accuracy of the devices objectively in comparison with manufacturing data [Dorozhynskii O., 2014].

Based on the results of the study it can be concluded that the accuracy of existing terrain laser scanners allows entirely to determine the real estate physical deterioration. These results are shown in Tables 3 and 4.

Thus, terrain laser scanning is a powerful tool for spatial modelling and object mapping. Modern possibilities of this method are rather attractive and give the chance of further improvement (increasing accuracy and velocity, TLS automation). The cost of TLS equipment is sure to be lower soon and as the result, it will become more available for firm valuating and appraisers themselves.

Standard requirements contain a significant part of subjectivity while determining physical deterioration. It is shown at Table 2. The application of TLS gives the possibility of accurate (and not nearby) valuation of constructive building component.

For example if the depth of joint destruction is from 2 to 4 cm and its area is from 30 % to 50 % and the crack width is from 2 mm to 4 mm then using table 2 it can be said that physical deterioration is in the range from 31 % to 40 %. But what is the reasonable rate of physical deterioration? The results of the studying are shown at Table 5 and at Fig. 2, 3.

Table 5

Determination of Physical Deterioration of Structural Building Components According to Their Quantitative Valuation

The depth of joint destruction, cm	The crack width, mm	The rate of the damaged area of building component, %	Physical deterioration, %
2.0	2.0	30.0	30
2.2	2.2	32.0	31
2.4	2.4	34.0	32
2.6	2.6	36.0	33
2.8	2.8	38.0	34
3.0	3.0	40.0	35
3.2	3.2	42.0	36
3.4	3.4	44.0	37
3.6	3.6	46.0	38
3.8	3.8	48.0	39
4.0	4.0	50.0	40

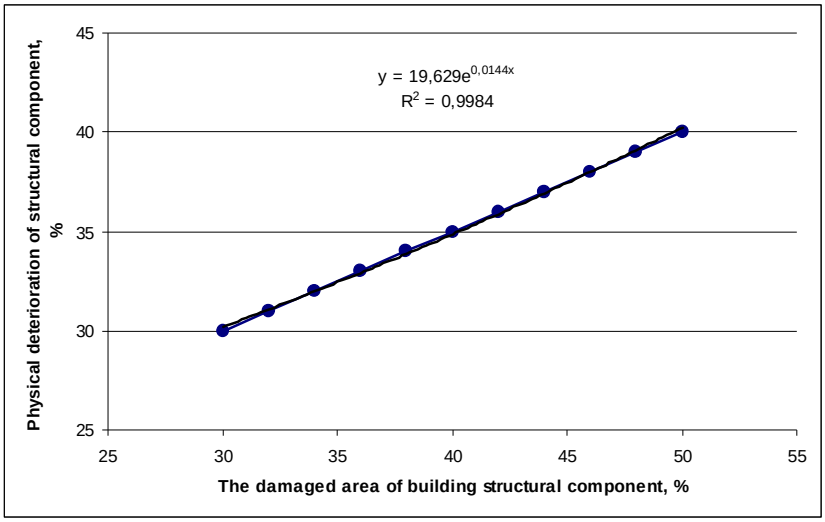

Fig. 2. Dependence rate of physical deterioration based on the damaged area of building structural components

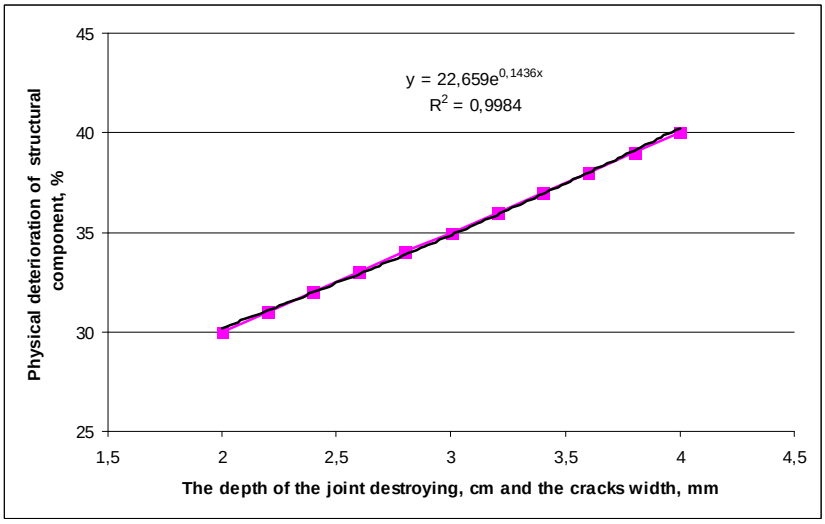

Fig. 3. Dependence rate of physical deterioration based on the depth of the joint destroying, cm and the cracks width, (mm)

Based on the got correlation (Fig. 2, 3) and applying terrain laser scanners in order to avoid subjective valuation, the possibility to prove the value of physical deterioration of building structural components and constructions has appeared. As the result, it gives the possibility to avoid "legal weak-points" of getting real estate market value. This method objectively both quantifies and quantifies real estate assessment.

The research practical implementation

It is necessary to know the entire real estate market value (land and land recreation). If the land market value with the set building on it is 200 thousand UAH and there is no functional and external deterioration then the creating cost is 500 thousand UAH.

As the result, the calculation (1) is in such form $I = I_{phys}$.

While valuating the building appraiser has conducted:

1. Physical building deterioration valuation by standard methods (classic)
2. Physical building deterioration valuation applying terrain laser scanning.

As the result of valuation insignificant defects have been found in bearing structural frames. The basement is laid with decorated brick. The rooms are located on the ground floor. Based on the physical object condition and its valuation it can be divided in two groups:

1. The first group includes the room where recently, before the valuation date, decorative repairing has been done. These rooms are in excellent condition. A new parquet, wallpaper, have been set. A new sanitary equipment, walls with ceramics, boiler have been set in the bathroom. All the defects of these rooms have been economically effective eliminated and as the result, recreating and deterioration is zero.

2. The second group includes all other rooms. These rooms are decorated worse, with lower quality. In general, they are in good and satisfactory condition, but to meet the current requirements they need decorative repairing.

Valuation done by an appraiser describes the state of the rooms as follows (Table 6).

The results of calculating physical building deterioration value by classic method of real estate valuation (based on Figs. 2, 3) are shown at Table 7.

The results of calculating physical building deterioration value by using terrain laser scanning are shown at Table 8. Having applied TLS the got results of the studying are shown at Table 5 and at Figs. 3, 4. The possibility has appeared to explain the physical deterioration value of building components and thus, to avoid subjective valuation which is shown at Table 8.

The results of calculating the market value of the entire real estate complex (land and land recreating) are summarized at Table 9.

Based on more precise determination of physical deterioration (complex deterioration) received by the market value of the entire real estate complex has been got (see Table 9). It has been under much smaller impact of appraiser's subjectivity. The physical real estate deterioration has been determined by using TLS method. The final derivations are 6350 UAH or that is 1 %. It is considered to be significant and important and thus, it shows the importance of using TLS for physical building and construction deterioration.

Table 6

Physical Room State of the Second Group

Name	Physical state
The floor	Parquet has threadbare and cracks. Linoleum has threadbare at the door and foot way.
Window spaces	Window frames have cracks and threadbare in walls. The cement has been lost in some places, part of the equipment has been damaged.
Doorways	Doorways have small damages and defects.
The interior	Ceiling painting has darkened. Wall painting has been darkened and dirty. There are some of the wall damages. Some decorative panels have been displaced from the walls.

Table 7

The Results of Calculating Physical Building Deterioration Value by Classic Method of Real Estate Valuation

Buildings components	Density of component	Physical deterioration value of the building component	Physical deterioration value of the building
1. Fundamental	4	10	0.40
2. Walls	20	13	2.60
3. Partitions	7	15	1.05
4. Ceiling	11	10	1.10
5. Roof	5	38	1.90
6. Floor	12	11	1.32
7. Steps	4	15	0.60
8. Windows and doors	12	25	3.00
9. Interior decoration	8	10	0.80
10. Others	8	15	1.2
11. Sanitary technical equipment including:	6.7		0.99
Central heating	1.6	10	0.16
Plumbing	0.5	20	0.10
Hot running water	1.4	25	0.35
Sewage	3.2	12	0.38
Total:	**100**		**14.96**

Table 8

The Results of Calculating the Physical Building Deterioration Value by Using Terrain Laser Scanning

Buildings components	Density of component	Physical deterioration value of the building component	Physical deterioration value of the building
1. Fundamental	4	10	0.40
2. Walls	20	15	3.00
3. Partitions	7	18	1.26
4. Ceiling	11	12	1.32
5. Roof	5	38	1.90
6. Floor	12	14	1.68
7. Steps	4	15	0.60
8. Windows and doors	12	25	3.00
9. Interior decoration	8	10	0.80
10. Others	8	16	1.28
11. Sanitary technical equipment including:	6.7		0.99
Central heating	1.6	10	0.16
Plumbing	0.5	20	0.10
Hot running water	1.4	25	0.35
Sewage	3.2	12	0.38
Total:	**100**		**16.23**

Table 9

The Results of Calculating the Market Value of the Entire Real Estate Complex

Calculating components	The classic method	The method of using TLS
Physical deterioration I_{ph}, coef.	0.1496	0.1623
Cumulative deterioration I, coef.	0.1496	0.1623
The recreation cost, UAH.	500 000	500 000
Cumulative deterioration, UAH.	74 800	81150
Displacement value, UAH.	425 200	418 850
The land plot value, UAH.	200 000	200 000
The value of the entire real estate complex, UAH.	625 200	618 850
The difference of the got results, UAH	6 350	
Deterioration coefficient	0.0101	
Deterioration rate	1.01 %	

The results

The importance of terrain laser scanning for calculation of building and structure physical deterioration has been learnt while studying. The result has been the basis for the development of a new methodology of real estate valuation. Today the value of building component physical deterioration is determined by visual observation with the help of the simplest devices (plumb, linear, hammer, etc.). The value of physical depreciation of separate structures, technical equipment or their parts is determined by comparing of the existing features of physical deterioration with those which have been found during the observation [Kirichek Yu., 2016]. TLS application gives the possibility to set accurately structural parts of the damaged real estate.

Scientific innovation

The research has been done based on the possibility of using digital laser scanning for determining the real estate physical deterioration. The necessity of using terrain- scanning method in order to improve the methodology of real estate valuation and determination its physical depreciation has been stated in the article. This method gives the possibility to avoid appraiser's subjectivity while calculating, and in accordance with "legal weak-points" of the got results of real estate market value. It has been defined that regulatory methodological documents of real estate physical deterioration are out of date and do not coincide with the real estate market requirements. That is why they need to be improved. Having done research by using TLS and the got mathematic equations give the possibility to prove the value of physical deterioration of structural building components.

Its practical significance

Using TLS for real estate valuation is of a great economic efficiency. It reduces the cost for determining the geometric object characteristics tenfold in comparison with traditional geodetic methods. Appraisers are recommended in their work to use pulse and phase laser scanners for determining real estate physical deterioration. Terrain laser scanning gives the possibility to get detailed structure of the real estate.

Conclusion

1. The basis of current standard methodological documents concerning real estate physical deterioration is out of date. The formality of the current method of calculation prevents getting accurate results of valuation.

2. The before suggested methods of determining real estate physical deterioration cannot be considered as final because they only determined object physical deterioration in general without determination its separate components (apartments, rooms, etc.).

3. It is suggested to use terrain the scanning method in order to quantify physical deterioration. It gives the possibility to avoid appraiser's subjectivity and thus, "legal weak-points" of the got real estate market value.

4. Appraisers are recommended while operating to use pulse and phase laser scanners in order to determine real estate physical deterioration.

Further research prospects

1. The necessity of improving standard methodological basis for determining real estate physical deterioration has appeared because of the further development of real estate market and the spread process of real estate valuation.

2. It is necessary to create the main working steps and the set of calculated models for real estate physical deterioration.

3. Methods of using terrain laser scanning is going to be conducted and applied in the practical activity of the appraisers in order to determine functional and exterior deterioration.

4. To study calculations of cultural heritage object market value having applied TLS.

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ЗАСТОСУВАННЯ НАЗЕМНОГО ЛАЗЕРНОГО СКАНУВАННЯ З МЕТОЮ ВИЗНАЧЕННЯ ФІЗИЧНОГО ЗНОШЕННЯ ОБ'ЄКТІВ НЕРУХОМОСТІ

Мета. Із розвитком сучасних методів наземного лазерного сканування (НЛС) об'єктів нерухомості, промислових територій, об'єктів культурної спадщини тощо актуальності набуває проблема застосування цих методів для визначення фізичного зношення будівель і споруд. Якість лазерних сканерів дала змогу інтенсивно розвивати прикладу сферу НЛС, а саме: визначення деформацій будівель та інженерних споруд, а також фізичного зношення їхніх конструктивних елементів як всередині, так і ззовні об'єктів нерухомості тощо. Сьогодні виникає необхідність впровадження нових сучасних методів з метою уникненні суб'єктивності оцінювача і відповідно до цього отримання реальної ринкової вартості об'єкта оцінки. **Методика.** Методика ґрунтується на необхідності використання методів наземного лазерного сканування для визначення фізичного зношення об'єктів нерухомості. В оцінці нерухомості зношення розглядають як основний чинник для визначення вартості будівель і споруд та визначають як втрата корисності, а отже і вартості за будь-яких причин [Kharryson H. S., 1994; K. Эkkert, 1997]. Серед головних чинників, що впливають на точність та якість лазерного сканування більшість фахівців виділяють такі основні чинники, як точність приладу (калібрування); умови сканування (атмосферні чинники); властивості об'єкта сканування (відбивна здатність); геометрія сканування; попереднє оброблення матеріалів сканування (Шульц Р.В., 2010). **Результати.** Виконані дослідження доводять важливість застосування наземного лазерного сканування для розрахунку фізичного зношення будівель і споруд та для розвитку методології оцінки нерухомості загалом. Сьогодні величина фізичного зношення елементів будівлі визначаються візуальним обстеженням з використанням найпростіших приладів (висок, рівень, лінійка, молоток тощо). Величина фізичного зношення окремих конструкцій, технічного обладнання або їхніх ділянок визначається за допомогою порівняння наведених у них ознак фізичного зношення з виявленими під час обстеження [Кірічек Ю. О. 2016]. Застосування НЛС дасть змогу точно встановлювати пошкодження конструктивних елементів нерухомості. **Наукова новизна.** Виконано дослідження пов'язані із можливістю використання цифрового лазерного сканування з метою встановлення фізичного зношення об'єктів нерухомості. У статті доведено, що з метою удосконалення методології оцінки нерухомості та визначення фізичного зношення необхідно використовувати методи наземного сканування, що допоможе оцінювачам уникнути суб'єктивності у розрахунках та відповідно "юридичної вразливості" отриманих результатів ринкової вартості нерухомості. Доведено, що нормативно-методична документація щодо оцінки фізичного зношення нерухомості застаріла і не відповідає вимогам ринку нерухомості і, отже, потребує вдосконалення. **Практична значущість.** Використання НЛС для оціночної діяльності має досить високу економічну ефективності, а саме здешевить визначення геометричних характеристик об'єкта оцінки в десятки разів порівняно із традиційними геодезичними методами. Оцінювачам рекомендують у своїй практичній діяльності використовувати імпульсні та фазові лазерні сканери з метою визначення фізичного зношення об'єктів нерухомості. Наземне лазерне сканування дасть змогу отримати детальні характеристики складових об'єкта нерухомості.

Ключові слова: фізичне зношення, наземне лазерне сканування, оцінка нерухомості, ринкова вартість нерухомості, будівлі і споруди.

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