Terrestrial Laser Scanning Technology Utilization Example in the Living Area Measurement as a part of Real Estate Valuation

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Abstract: The value of real estate is currently the requested data mainly in the processing of loan. Value has several forms in the forensic environment. In contrast to value, the price is a direct indication of what the property is acquired for. However, if we determine the value, we will in any case use the obtained indicator per unit of measure and the number of units of measure. Units of measurement - area or volume are obtained by measuring or subtracting from the documentation. If they are obtained by measurement, it is necessary to follow the relevant standards and legislation. The measurement procedure is important for measurement. We focused on the resulting standard measurement and TLS measurement in this article.

Keywords: TLS, area measurement, forensic engineering

Abstrakt: Hodnota nehnuteľnosti je v súčasnosti žiadaným údajom prevažne pri vybavovaní úveru. Hodnota má v znaleckom prostredí viacero podôb. Na rozdiel od hodnoty je cena priamym údajom za akú je nehnuteľnosť nadobudnutá. Ak však budeme zisťovať hodnotu, využijeme v každom prípade na výpočet získaný ukazovateľ na mernú jednotku a počet merných jednotiek. Merné jednotky – plocha alebo objem sa získavajú meraním alebo odčítavajú z dokumentácie. Pokiaľ sú získané meraním, je potrebné sa riadiť príslušnými normami a legislatívou. Pri meraní je dôležitý postup merania. Na výsledné meranie štandardným spôsobom a meranie prístrojom TLS sme sa zamerali v tomto článku.

1. Introduction

Estimation of the value of a property is a frequent subject of price determination for the purpose of purchase, loan settlement, inheritance valuation, etc. This issue is mostly used in expert evidence proving – forensic engineering. The price of the property can be expressed as a financial amount that the buyer pays to the seller for a certain matter. Price depends on agreement between both parties. The price of a property can be different, but also the same as its value. An example could be the sale of one apartment by different realtors (each will probably have a different price - depending on profit), or sale without a realtor (the price will be lower, as it is reduced by the realtor's fee). The property price is affected by many factors, which are often subjective, and the chartered forensic expert cannot include them in the calculation of the general value. The expert's role is to be objective and impartial.

1.1 The meaning of determination of the value

The task of the chartered forensic expert (further on as "Expert") is to determine the general value of the property that it has in a particular time and exact location. The Expert determines the value to the best of his / her conscience and consciousness and is responsible for the output value. Detailed calculation of the general value is described in the appraisal. In order to explain the importance of accurate measurements in determining the value of a property, it is necessary to describe the basic terminology and link it properly with Expert´s practice [13].

Appraisal is prepared for a specific purpose - a legal act, where each act has its own specifics, that must be respected. The purpose of the appraisal may be:

1. an inheritance procedure,
2. a lien,
3. a conveyance of property,
4. a non-monetary company deposit;
5. a registration of the building under construction in the Land Registry,
6. a lease of land,
7. a valuation of business components,
8. a settlement of non-share ownership of spouses, settlement of share ownership,
9. a determination of the easement value (easements of way, etc.)
10. other (property distrainment, etc.).

1.2 Basic terminology

In existing Slovak legislation [13] there are following terms related to assessment (estimation of the value) defined:

Initial Value of the Construction - Initial value is the Expert´s appraisal of a Value, that is to be considered as the cost of construction at a time of evaluation without the VAT.

Technical Value – Technical value is the Expert´s appraisal of Initial value lowered by the value of amortization.

General Value – General value is the value that Expert specify in the appraisal. This Value should match to selling price that is to be met at free market, assuming that both the buyer and the seller act with caution and are both appropriate informed, without side motives (rapid selling, selling to a family, etc.). Many factors influent the General value, such technical state of property, property equipment, actual status of real estate market, etc., that the Expert needs to consider and reflex in the calculation.

Technical State of the Construction – Technical State of Construction is the percentual representation of the actual state of the construction.

Profit Value – Profit value is the Expert´s estimate of actual value of future disponible profit of using the property for rent, discounted by risk fee.

Amortization of the Construction – Amortization of the construction is the percentual representation of the construction´s amortization.

The Age of the Construction - The Age of the Construction is the age of the construction counted in years from the beginning of its operation to the date of evaluation / estimation of the value.

Residual Lifespan of the Construction - Residual Lifespan of the Construction is the estimate lifespan counted in years until the expected decommission.

Expected Lifespan of the Construction - Expected Lifespan of the Construction is the expected (or specified) overall lifespan of the construction counted in years.

In the existing Slovak legislation, there are no definitions for terms related to renting specification of the property. By applying the general value definition analogy, following definition of general value of the rental property could be presented:

General value is the final objective value of the properties and constructions that is the Expert´s estimate of its most likely price to the day of the estimation of the value which should be reached at

market maintaining the free competition and faithful sales, when both the buyer and the seller act with caution and are both appropriate informed, without side motives. The result of estimate is the general value with the VAT.

General value of the Construction – there are following methods used to determine the general value of the construction:

- Comparation method
- Combination method (only for the construction being able to generate profit from rent)
- Location differentiation method (LDM)

Location differentiation method [13] is based on following relationship:

$$GVf = TV * cLD, \quad (1)$$

where:
GVf – general value of the flat [€],
TV – technical value of the construction without VAT,
cLD – coefficient of the location differentiation expressing the impact of the location and other factors impacting the general value at a certain location and particular time

To determine the coefficient of the location differentiation method, methodology incorporated in USI are used. The principle is based on the determination of the value of average selling coefficient in relation to the location and the type of the property, which is further used as input value for partial coefficients for individual quantitative classes. Average coefficients of LDM used are based on experience. The process if followed by evaluation of multi-location criteria (assigned to quantitative classes) when the average value of the LDM coefficient is objectivized to final value, applicable for particular evaluated property. Within the objectivization process, each location criterion has its specific impact to the value.

Determination of initial and technical value of the construction:

Various budget indicators are used and they are all published in the official methodology "Metodika výpočtu všeobecnej hodnoty nehnuteľností a stavieb" (ISBN 80-7100-827-3). Coefficient of price level is based on the latest known statistical data published by Statistical Office of the Slovak Republic.

Initial Value of the Construction [13] is determined according to following formula:

$$VH = M * (RU * kCU * kV * kZP * kVP * kK * kM), \quad (2)$$

kde:
VH – initial value [€],
M – number of measuring units,
RU – budget indicator according to methodology in the price level of 4th quarter of 1996,
kCU – coefficient expressing the price of the construction works and material growth between the 4th quarter of 1996 and the latest know data
kV – equipment impact coefficient of evaluated property,
kZP – built-up area impact coefficient of evaluated property,
kVP – construction height impact coefficient of evaluated property,
kK – construction and material related coefficient,
kM – local area impact coefficient.

Potential damages or unfinished works are taken into account by percentual estimate of finished individual construction or equipment of the construction during the initial value determination.

Technical value [13] of the Construction is determined according to following formula:

$$TH = VH - HO \quad \text{or} \quad TH = VH * (TS / 100) \quad (3)$$

By written above text, authors would like to bring attention to the significant meaning of determination of the bill of the quantities for the whole process of estimation of the value of the property. In particular, the item M – the number of measuring units if the formula for determination of the initial value as the initial value sets the base for technical and general value.

The flat is the habitable room or a set of habitable rooms with accessory organized into functional unit with its own lock, suitable for permanent living. (6) Accessory of the flat for the purposes of this legislation are the rooms, that serve as communication, economy or hygienic functions of the flat. [13]

Accessory of the flat is defined also by [9] in similar manner. By flat, for a purpose of this legislation, we understand a room or a set of rooms, that are according to building authority dedicated to permanent habitation and could only serve to this matter as individual units [17].

Floor (utility) area – By floor area of the flat, for the purposes of this legislation, we understand floor area of all rooms of the flat and rooms, that serve as accessory without the area of loggia and the area of balcony. Floor (utility) area is the sum of area of all habitable rooms and accessory rooms of the flat without the area of balcony, loggia and terrace.

Attic - internal space of a house accessible from the last aboveground level delimited by timber roof and other construction; may serve to several purposes.

Loft - internal space of house delimited by timber roof usually accessible from the last aboveground level without primary use for living [9]. Floor area calculated from its dimension stated in drawings according to [9] are suitable for a design of a residential building. Overall floor area of a room is included besides the areas with lower than 1300 mm of a ceiling height. The area of oriels and niches are included providing that are at least 1200 mm wide, 300 mm deep and 2000 mm high from the floor level concurrently. In addition, the area occupied by heating units, installation objects, technical equipment or machinery and kitchen units is included. However, neither the area of window and door recesses and nor the area occupied by built - in furniture shall not be included according to [8].

Built-up area - the area of the plan view defined by the outer perimeter of the vertical structures of the considered whole (buildings, floors or parts thereof); on the first floor, it is measured above the rootstock or under the wall, insulating linings are not included. For objects not covered or semi-covered, the built-up area is defined by the boundary lines led by the outer faces of vertical structures in the plane of the adapted terrain [7].

JKSO - Decree FŠÚ No. 124/1980 Coll. on the uniform classification of construction objects and works of a productive nature. (from 01.01.1981 till 01.05.2000)

KS - Decree of the SO SR No. 128/2000 Coll. Declaring the classification of buildings (from 01.05.2000 to 15.07.2010)

ŠKS – Decree of the SO SR No. 323/2010 Coll. issuing a statistical classification of buildings (from 15.07.2010)

Detailed definitions of individual terms and abbreviations from the perspective of various technical documentation or legislation have already been the subject of specialized literature [1, 16, 17, 18, 19]. In the area of financial evaluation of buildings, the terms related to the determination of the extent and content of the buildings are a key comparative basis. The baseline is calculated on the basis of the budget indicators, the units of measurement of the object being evaluated must be calculated according to the technical standard on the basis of which the selected budget indicator was compiled. Catalogs of budgetary indicators [4, 10, 11] they work with concepts such as floor space and built-up area or enclosed space, determining the "inclusion" or "non-inclusion" of certain constructions or spaces in the content of the terms. [1, 5, 6, 7, 8, 9]

2. Measurement

Pursuant to the Methodology for calculating the general value of real estate and buildings [3, 14], the measurement and calculation is performed as follows:

The Expert always carries out the inspection and orientation personally in the presence of the owner of the property, focusing on the dimensions of the building that will be used in the calculations. If the project documentation is provided, it will make a comparison with the factual situation, the decisive factor being the factual situation, which must match the data in the cadastral of the property. [14]

For the purpose of measuring and calculating the area of buildings, the individual measured areas, areas and lengths are defined. The unit of measurement shall be calculated in square meters, in cubic meters or in common meters. Round to two decimal places. Measurements shall be made to the nearest centimeter. [14]

In the case of length measurements, the correct length measurement is considered to be the original length if the control measurement does not differ by more than 0,50% of the originally measured length up to 20 m and 0,25% of the originally measured length for measurements over 20 m. [14].

2.1 Meter

Valid meter definition dated back from 1983: Meter is the length of the light path under vacuum over a time interval of 1/299 792 458 seconds [12]. So far, the prototype of the meter has served and will continue to serve as a model to produce copies, from which all the measuring instruments produced in the individual territories using the metric system are derived. Because it is stored in an archive, it is sometimes called an archive meter. The final prototype of the meter was developed in 1886. It is a platin-iridium rod with a cross-section in the shape of H, which is marked with two scratches for exact distance of 1 m. According to the prototype a total of 40 identical rods were produced.

2.2 Metrology

In the currently valid legislation [15] (157/2018 Act on metrology and on amendments to some acts) we also find a law to ensure the accuracy and uniformity of measurement and metrology in the field of metrology, which regulates at selected points also: b) measuring unit and its use (c) groups of instruments, (f) requirements for a specified instrument, (g) use of a specified instrument and use of a mandatory gauge, (m) method of metrological control of a specified instrument and calibration of a mandatory instrument and persons who may perform metrological inspection and calibration; official measurement and others.

For the purposes of this Act:

- measuring unit is a real scalar quantity defined and accepted by convention, with which it is possible to compare any quantity of the same kind to express the ratio of two quantities in the form of a number,
- a metered material measure or device used to carry out measurements, alone or in conjunction with one or more attachments;
- the second measuring instrument is a group of measuring instruments which are designed to measure the same quantity, are based on the same measurement principle and share some characteristics in common,
- type of measuring instrument the final design of a measuring instrument of a particular design according to the technical documentation applicable to that type of measuring instrument, all components having an impact on the technical characteristics and metrological characteristics defined in the technical documentation, produced by the same manufacturer;
- calibration of a measuring instrument means a set of operations which, under defined conditions, determine the relationship between the values indicated by the measuring instrument or measuring system or the values represented by the materialized measure or reference material and the corresponding values of the quantities realized by the standard;
- designated measuring instrument for mandatory metrological control or conformity assessment,

• mandatory calibrated measuring instrument or product intended for mandatory calibration,

• a user-specified measure a public authority, entrepreneur or other person using a specified measure or a value indicated by a specified measure in a payment-related measurement, in the protection of health, safety, property or the environment, in prepacking, in another public domain a life where a conflicting interest in the measurement result may arise or where an incorrect measurement result may harm the interest of a natural person, a legal person or the public, or if so provided by special regulations,

• use of a specified gauge means measurement by a specified gauge by the user of the specified gauge.

Pursuant to Section 7 of the same Act [15], Legal Units, the legal unit of measurement under this Act is (a) a base unit of a set of units of measurement (hereinafter referred to as the "base unit"): 1 (one) meter as a unit of length, the symbol of which is m.

Under Section 8 of the Measuring Instruments Group:

(1) For the purposes of this Act, measuring instruments are classified into the following groups:

• national standards and other standards,

• certified reference materials and other reference materials,

• designated gauges and mandatory gauges,

• other gauges.

(2) Other measuring instrument is a measuring instrument which is not a national standard, other standard, certified reference material, other reference material, designated measuring instrument and compulsory calibrated measuring instrument. [15]

Pursuant to Section 11 Designated measuring instrument

(1) The classification of a measuring instrument into a group of designated measuring instruments is determined by its purpose and use

• for payments-related measurements

• in the protection of health, safety, property or the environment,

• in prepacking,

• in another area of public life where conflicting interests may arise in the measurement result or where an incorrect measurement result may harm the interests of the natural person, legal entity or the public; or

• for measurements, if required by special regulations. [15]

(2) Measurement related to payments is in particular measurement

- in business relations
- To determine the price when selling directly to the consumer; or
- for the purpose of calculating prices, fees, tariffs, duties, taxes, preferences, fines, refunds, indemnities, insurance or similar payments.

(3) Without a metrological check or conformity assessment[1)], the designated measuring instrument shall not be placed on the market and used.

(4) When using a designated measuring instrument for the purpose pursuant to paragraphs 1 and 2, the value of the measured quantity shall be the value of the materialized measure or the value indicated by the designated measuring instrument. [15] Subsequently, Article 16 of the Act lays down conditions for the use of a designated measuring instrument

DECREE 161/2019 Coll. The Office for Standardization, Metrology and Testing of the Slovak Republic of 27 May 2019 on measuring instruments and metrological control prescribes, inter alia, in § 1:

• the types of measuring instruments and their area of use,

• details of the procedure for type-approval of the designated instrument and the procedure for verification of the designated instrument,

• details of the technical requirements and metrological requirements for each type of measuring instruments, including the methods for their technical testing [12].

The Decree also contains details of the designated measuring instruments and their parameters in Annexes 1 and 3. Annex 1 provides:

DRUHY URČENÝCH MERADIEL

1. GEOMETRICKÉ VELIČINY

1.1. Dĺžka

položka	druh určeného meradla	metrologická kontrola			čas platnosti overenia v rokoch	číslo prílohy
		národné schválenie typu	národné prvotné overenie	podľa osobitného predpisu*)		
1.1.1	Materializovaná dĺžková miera					
	a) kovová	nie	nie	áno	5	3
	b) z iného materiálu	nie	nie	áno	2	3

Figure 1. The part of Appendix no. 1 of the Decree 161/2019 – Types of designated meters

4. Metrologické požiadavky

4.1 Dĺžková miera sa rozdeľuje podľa jej presnosti do triedy presnosti I, II alebo III.

4.1.1 Najväčšia dovolená chyba pri následnom overení dĺžkovej miery na akejkoľvek vzdialenosti medzi ľubovoľnými dvomi za sebou bezprostredne nenasledujúcimi značkami stupnice je vyjadrená v **mm** ako funkcia dĺžky vzťahom $(a + b\,L)$ v **mm**, kde a a b sú koeficienty určené pre každú triedu presnosti podľa tabuľky č. 1 a L je dĺžka zaokrúhlená na nasledujúci celý **m** smerom nahor.

Tabuľka č. 1

Trieda presnosti	***a***	***b***
I	0,1	0,1
II	0,3	0,2
III	0,6	0,4

Figure 2. The part of Appendix no. 3 of the Decree 161/2019 – Metrological requirements.

In accordance with the guidelines of the Methodology for calculating the general value of real estate and buildings [14] and its stated measurement accuracy, the accuracy class specified in the metrology legislation does not have a significant impact, but a dedicated measuring instrument with calibration protocol and accuracy class I or II must be used. The conclusion is therefore that under Act 157/2018 on metrology [15]:

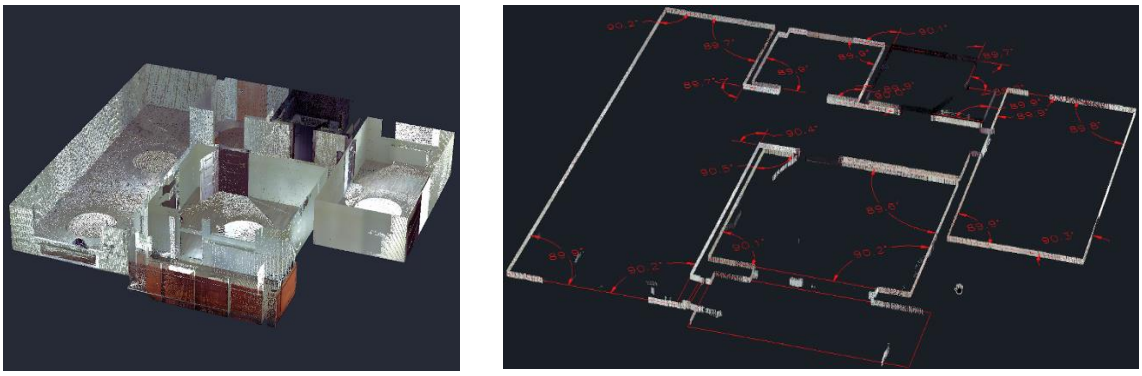
- the user of a designated measure is a public authority, entrepreneur or other person - is also an expert (Section 2 (1) of Act No. 382/2004 Coll. on experts, interpreters and translators)
- Pursuant to Section 11 Designated Scale; used by an expert in measurements related to payments; used by an expert in another area of public life where conflicting interests may arise in the measurement result or where an incorrect measurement result may harm the interests of a natural person, a legal person or the public and for the purpose of calculating the price,
- the expert shall comply with Decree 161/2019, in particular Annexes 1 and 3.

2.3 Alternative measurements

Currently there are alternative measurements forms that use the technology and digital environments. For example, measuring surfaces with laser distance-meters or use of TLS devices [2] that both work with high precision. They are calibrated and their software potential enables direct surface or volume calculations. The methodology for measuring built-up or living areas, where the various factors identified in the measurement would be accurately defined and taken into account, has not yet been established. For example, at what height to measure the size of the room, at which point (in the middle, on the edge with respect to furniture ...), how many measurements need to be done for different room types and different room sizes. There is no guidance for older buildings with uneven walls (verticality, parallelism of walls) that have different widths at floor, at a height of 1m and at a ceiling level. Also, the different shapes of the floor plan could affect the measurement and the resulting calculation of the area, where various Experts can obtain different results further used as input data to the value calculation. At new-built objects, the resulting difference in the measured areas could be minimal or even negligible. In this case where the Expert has floor plans and the difference is not greater than stated in the methodology [14, 3], the expert uses the values defined in the project.

2.3.1. Case study

To demonstrate the measurement of the flat area, which subsequently serve as input data to the estimation of the value, we performed the measurement in two ways. The first method was a retracting meter with a length of 5 meters and a class of accuracy I. The measuring method was chosen with regard to the methodology [14]. The second method was undertaken by Leica ScanStation2, which uses 3D spatial scanning technology with high precision. The scanned space can be visualized, measured and verified in the 3D environment of the various CAD software with 3D support or special software supplied by the device´s manufacturer. Among other things, it is possible to directly define the height at which it is possible to project the floor plan of the rooms and then calculate the area by programmed functionality. The area could be retrieved using algorithms of specialized software. Its accuracy is high and allows to take into account the curvature, respectively the unevenness of walls.



(**a**) (**b**)

Figure 3. The resulting data of a two-room apartment according to Act - TLS measurement

We rounded the resulting value according to the methodology ("Vyparina") to two decimal places. Tables with measurement results are shown in Tables 1 and 2, a comparison table with measurement results is below in the article - Table 3.

Table 1. Measurements obtained by rolling meter

Room name and calculation	**Floor area [m²]**
Calculated floor area	72,12
Balcony 2,07*4,1	6,56

Table 2. Measurements obtained by TLS

Room name and calculation	**Floor area [m2]**
Calculated floor area in CAD environment	72,88
Balcony 2,07*4,1	6,56

Table 3. Overall summary of the measurements

Room name and calculation	**Floor area [m²]**
Measurement by rolling meter	72,12
TLS measurement	72,88
Difference	0,76

Numerous measurements were made to determine possible differences in measurement results of which five measurements were performed in two-room apartments, five in three-room apartments and five in 4-room apartments. The differences vary from 0.08 m² at a two-room apartment to 0.93 m² at a four-room apartment. The resulting values are shown in the figures below.

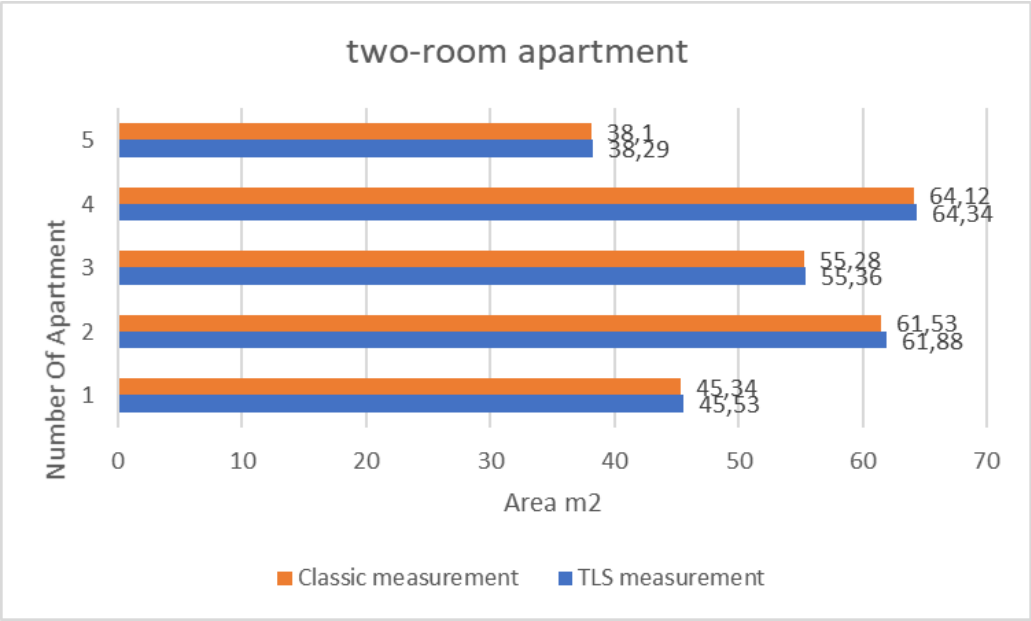


Figure 4. The resulting data of a two-room apartment according to Act - TLS measurement

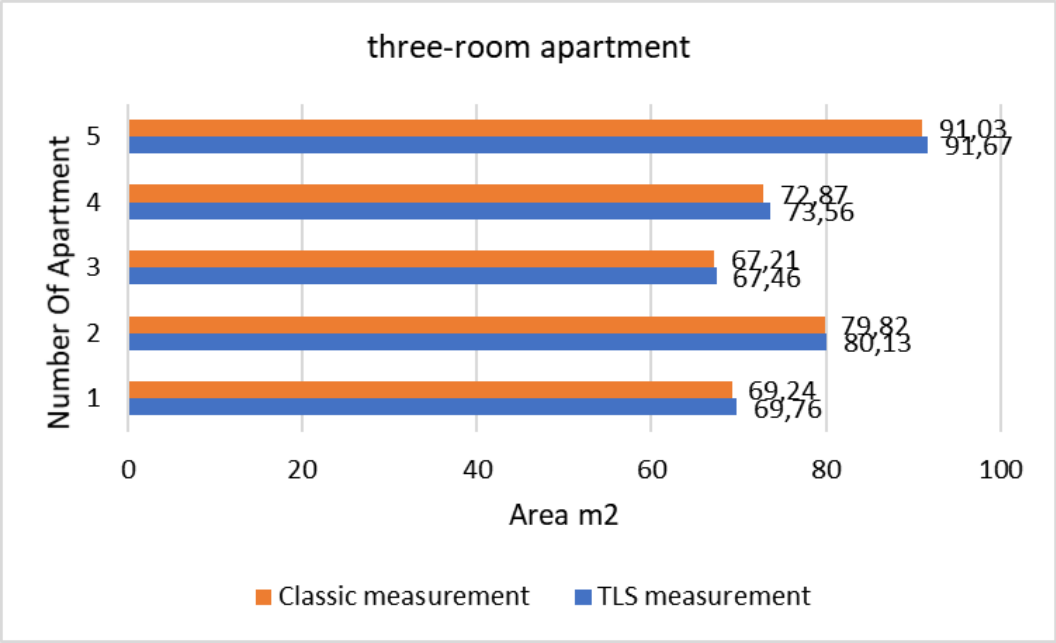


Figure 5. The resulting data of a three-room apartment according to Act - TLS measurement

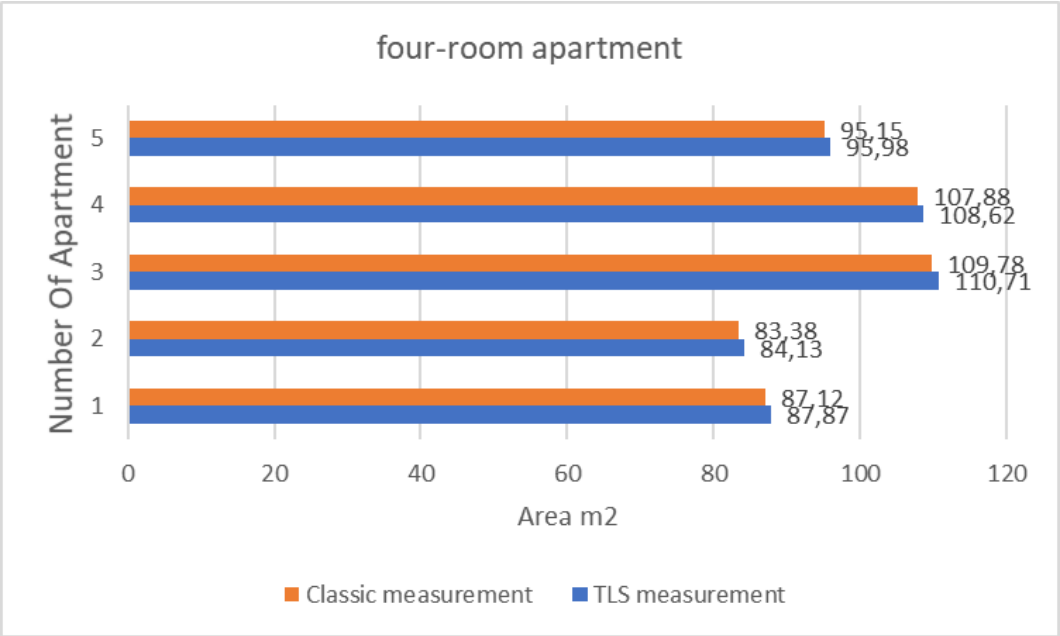


Figure 6. The resulting data of a four-room apartment according to Act - TLS measurement

After performing the verification measurements using TLS versus standard measurements, we reached the following conclusions:

- an average deviation of 0.206 m² for two-room apartments with an average area of 53.08 m²,
- an average deviation of 0.482 m² for three-room apartments with an average of 76.52 m²,
- an average deviation of 0.800 m² for four-room apartments with an average of 97.46 m².

The difference in the measurement results is probably due to the number of measurements and due to rounding of the values. Using TLS, there is single measurement derived from the CAD environment and only the result value is rounded. In the process of standard measurement, there is every single length value rounded. After multiplication of individual values, further rounding is being done. In conclusion, rounded totals are added up. It can be stated that the more rooms (measurements), the greater the difference in the measurement result.

3. Results

The results of the measured values demonstrate the accuracy of the measurement using current technology. The method of measurement using standard instruments (laser distance-meter or a rolling meter with accuracy class I to II) brings a certain difference to the resulting area after rounding the measured lengths. The measuring with a rolling meter was carried out in the center in approximate distance of 1m from the floor level and the measurement was undertaken twice to ensure high precision. The result of each length measurement was rounded in terms of methodology. After the measurements, the lengths were incorporated into the table from which the resulting flat area was mathematically calculate. The measured data from the TLS device were processed in digital form using a computer. The difference could be potentially in the measuring and rounding system of each dimension continuously throughout the measurement.

On the other hand, the rounding after the measurement undertaken by TLS device was at the very end of the process, so the whole measurement was carried out with high accuracy. This difference could therefore have an impact to the buyer and seems to be advantageous for the seller.

4. Discussion

Both measurement methods can therefore be considered as fully respecting the current methodology and legislation at the same time. However, the measurement using innovative

technologies can contribute in the field of detection and specification of the exact area of the residential or non-residential buildings. Both measurement procedures are in line with the processes prescribed in the methodologies, but the result may differ significantly due to the rounding up. So in the matter of fact, considering the price per square meter, the method chosen may affect the final value of the property (technical, initial and general), however, it is corrected by several coefficients in the following procedure.

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