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ASSESSING THE INFLUENCE OF ON-SITE LIGHTING CONDITIONS TO THE POTENTIAL VARIABILITY OF THE 360 ° PHOTOGRAMMETRY USABILITY

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ABSTRACT

Today's technologies enable efficient data management and generally contribute to effective control of the construction process. There are various ways of focusing on a real construction project based on laser or digital camera measurements, however, the quality of outputs is depending on the lighting conditions. Proper lighting conditions greatly affect the result of the processed record, especially its final texture, geometry, and affect any errors in the measured values. There are various lighting conditions on the construction site, which affect the quality of the documentation made. While in the outdoor parts this situation is affected by daylight, inside the building we must rely on artificial lighting and as a result there are many parts without sufficient lighting, or the lighting is completely absent. In this article we focus on the evaluation of the impact of lighting in documenting the course of work on the site using 360 ° photogrammetry, especially in relation to verification of geometric accuracy, position of structures and current work in progress and follows the analysis of standard and technical requirements to determine appropriate ways to ensure adequate lighting.

Key words: *BIM, as-built documentation, photogrammetry*

1 INTRODUCTION

Digital technologies are becoming an increasingly common part of construction, enabling greater process automation. However, the application of these technologies requires increased demands on the knowledge, skills and abilities of stakeholders in the field of information technology.

Key goals for the use of innovative technologies are:

- faster data capturing,
- error reduction,
- higher quality,
- automation of processing.

All mentioned goals are related and they are applicable in the field of construction progress monitoring. When it comes down to quality, appropriate processes needs to be employed, using up-to-date technology to make it more effective.

2 RESEARCH METHODOLOGY

To evaluate the impact of lighting when documenting the course of work on the construction site using 360° photogrammetry, **we chose the method of analysis and experiment**.

The first part of the work includes an evaluation of the **current state of the art**, the possibilities and benefits of documenting buildings photogrammetrically. **In the second part**, we focus on the

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measurements themselves **under different lighting conditions** inside the building, as this problem is rarer in the outdoor environment and the analysis of the collected data. In the last part we formulate conclusions, evaluated on the basis of our own data, obtained from measurements.

The possibility of detail for verifying the geometric accuracy, the position of the given structures and the current work-in-progress increases by an order of magnitude with the use of suitable lighting, especially during measurements inside the building. **The experiment was evaluated with focus to two use cases - construction progress** and **suitability for ex-post measurement** based on photos. The range of values for evaluation were set, where 2 represents recognizable, 1 barely recognizable and 0 represents not recognizable. This scale was applied for both cases, evaluated and presented in charts.

3 PHOTOGRAMMETRY IN THE CONSTRUCTION

Different forms of control in the individual phases of the life cycle take up a substantial part of the work not only of the investor but also of other stakeholders and it is clear that using available technologies it is possible to perform these activities more efficiently. Interactive control of construction works should, in principle, ensure consistency between planned and completed works, thus contributing to the potential use of a tool for automated verification of crucial parameters of the construction work. Systematic 360° photogrammetry replaces the traditional work methods of focusing on the original state, reducing in particular the time spent in situ and also the need to repeat the measurements, especially with complicated geometric shapes of elements. As a result, it can represent added value for the project, increase the efficiency of the construction documentation and eliminate errors from the inaccuracy of the documentation of the current state. The goal is not only to reduce costs, with additional data collection, but also to increase the quality of the project.

3.1 Building Information Modeling

Building Information Modeling is elementary tool for increasing the efficiency of processes, including control and verification activities. The virtual 3D model itself is undoubtedly a more suitable solution compared to 2D documentation, especially in terms of possible interpretation. This reduces the number of discrepancies in the coordination of project documentation, construction work, operation and maintenance of buildings. Digitization of data, in general, not only enables faster processing of information, but also significantly reduces the possibility of errors caused by incorrect writing, sketching or incorrect interpretation of the record in cooperation with the worker who made the measurement in situ and the 3D model processor.

The use of the virtual model therefore allows to obtain more accurate electronic data allows faster and more reliable identification of possible problems. All information can be obtained directly from the model and it is not necessary to search for information about structures in individual drawings, technical reports or in the construction log. Different forms of control in individual phases of the life cycle take up a substantial part of the work not only of the investor but also of other stakeholders and it is clear that using available technologies it is possible to perform these activities more efficiently. Interactive control of construction works should, in principle, ensure consistency between planned and completed works, thus contributing to the potential use of a tool for automated verification of crucial parameters of the construction work. [1], [2], [3].

During construction, we often encounter the requirement to document the current state as a basis for the design plan. In the traditional process, this represents a very complex task, which has a number of shortcomings. The main shortcomings can be time consuming, inaccuracies in the measurement, complex determination of the mutual position of different rooms, respectively. objects and the absence of the third dimension, which is necessary especially when surveying pipelines and distribution. In addition, such a process cannot be automated.

We encounter a similar problem when checking the design of structures, respectively. construction, whether it is an ongoing inspection or a final one, upon handover of the construction. The inspection consists of manual operations that require a thorough knowledge of the project and are time consuming. The number and accuracy of inspections are thus very limited by the time in which it is possible to verify the execution, whether in terms of position, type accuracy, possible absence of the element. Checks must therefore be carried out selectively in direct proportion to the seriousness of the consequence of possible confusion and the results cannot be effectively delivered to the other party. With classical methods, there is often a need for additional targeting and site visits during data processing. The lighting requirements for carrying out the activities themselves are defined in the standard [9]. However, the requirement for lighting affecting inspection activities on site is not specified in the standard [10]. During the measurements, there are various lighting conditions on the construction site, which affect the quality of the prepared documentation. While in the outdoor parts this situation is affected by daylight, inside the building we must rely on artificial lighting and as a result there are many parts without sufficient lighting, or the lighting is completely absent. The lighting conditions have a direct effect on the level of usability of the captured photo documentation.

360 ° photogrammetry technology creates a precondition for a precise and effective approach not only for the creation of documents for the control of construction activities, but also today allows connection to a 3D model of a building in a BIM environment (Holobuilder, Dalux, etc ...). By comparing the planned 3D BIM model with the model created on the basis of actual measurements (documentation of the actual design), it is possible to generate differential models with a certain degree of automation. The analysis of differential models in the BIM environment will be part of the new tools and will have a decisive influence on the final assessment of work quality, verification of correct placement of objects and structures in space, as well as meeting quality requirements (geometric deviations) [5], [6].

The number of projects for which an information model of the construction is available is increasing year-on-year, and at the same time the experience of individual participants in the life cycle is increasing. The analysis of the BIM Association of Slovakia, which was carried out in 2020, shows that the current BIM implementation rate is 17%.

If we look at BIM from a procedural point of view, CDE (Common Data Environment) today is used only by 30% of active BIM users (about 5% of the market). A similar situation is in the management of processes and projects in terms of the requirements formulated in the BEP (BIM implementation plan). As many as 67% of active users do not manage BEP-based processes, which is due to the low BIM requirement from the position of customers. We can therefore assume that the connection of digital forms of control with BIM will achieve higher application usage in practice.

3.2 Impact of Lightning Conditions to the Usability

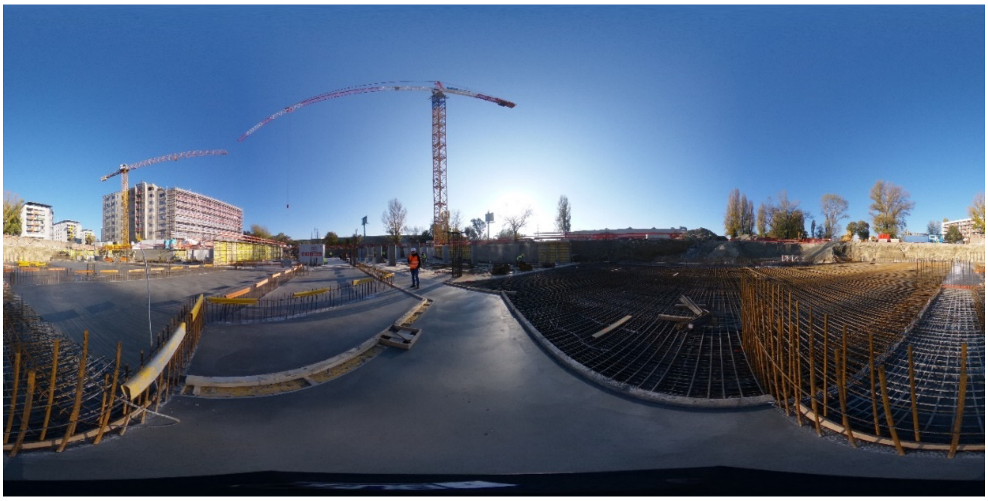
In many case studies, focusing mainly on outdoor measurements, the authors report the need to adapt the measurement date to optimal lighting conditions in order to achieve relevant results. In the case of measurement underground or indoors, the optimal lighting conditions cannot be achieved without the use of artificial lighting.

The authors focus on the analysis of modeling in low light or at night [7]. The aim of their research was to examine the reliability of images obtained at night for the production of digital surface models (DSM) for the detection of changes.

Experiments aimed at assessing the effect of different lighting conditions [8], distance from the subject, camera settings and photo overlaps showed that the lighting method was identified as insignificant if the scene was adequately lit. It has been found that distance from the subject has minimal effect on the accuracy of the results and that camera settings have a significant effect on the photogrammetric quality of the images. When measuring planar orientations, increasing the resolution of the photograph was preferred. Changes in focal lengths (F-stops) affect depth of field and image quality in situations where more angles are needed to survey orientation. Photo overlay is very important for proper 3D reconstruction, and a minimum of 60% overlap between pairs of photos is ideal to avoid unnecessary processing, resulting in a high volume of data leading to lower processability.

3.3 Exterior vs Interior Capturing

It is true that good lighting conditions will significantly affect the result of the photogrammetric model: its texture, geometry and potential errors. Although many unsatisfactorily lit scenes can be additionally modified by software, it is true that the more lighting we have under control during shooting, the less work we have to do with their processing. Inside the building, the lighting conditions have a significant effect on the photo documentation. Due to the construction, we have to rely on artificial lighting on the construction site, as many parts are not only without natural daylight, but in many cases, they are insufficiently lit by artificial light, or the lighting is completely absent. The need to illuminate the premises depends on how the photo is used again and the level of detail in which it will be inspected.



Details:

RICOH THETA Z1

1/32s f/5,6 2,57mm

ISO 100

6720 x 3360

8 MB

Fig. 1 Exterior on-site capturing, daylight

Details:

RICOH Theta V1

1/10 s f/2 1,3 mm

ISO 1600

5376 x 2688

3,2 MB

Fig. 2 Interior on-site capturing, artificial lightning

In the case of spot (directional) lighting, in unlit areas, resp. in poorly lit areas, there is a problem of shadows and in the direction from which the light comes, an area is created that is too dark and is therefore unsatisfactory for some forms of control. The use of a diffuse spherical light source appears to be a suitable solution. The advantage of a diffused light source is that light comes from all directions and evenly illuminates the surface of the entire object, so that no hard shadows are created. Measurements in outdoor conditions, in natural light, do not require the use of artificial lighting. On the photo documentation it is possible to identify the position and interface of structures, or to examine surfaces in detail.

3.4 Legislative framework

There are no standards and legislative in the field of lightning conditions needed for capturing purposes. We can only rely on the actual lightning situation on-site that is determined by type of work performed at that spot because according to the standards for visual tasks to be performed accurately and efficiently, adequate lighting must be provided at the site. These requirements also apply to work on the construction site and it is necessary to provide lighting for work performed with reduced visibility, respectively at night.

The framework is defined by Details on lighting requirements at work are set out in the Decree of the Ministry of Health of the Slovak Republic no. 541/2007 Z. z., and Law No. 355/2007 Z.z. on the protection, promotion and development of public health, as amended, along with Regulation of the Government of the Slovak Republic No. 391/2006 Z.z. on the minimum safety and health requirements for the workplace. According to a special regulation, workplaces must, as far as possible, be lit by daylight as far as possible and equipped with artificial lighting of adequate safety and protection of workers' health. Lighting conditions are further defined in the national standards STN EN 12464 – 2 [9].

In terms of the division into the type of light that we take into account when performing photography, we distinguish between natural light - daylight, artificial light and their use in combination. Natural light is light coming from the sun either as direct sunlight or diffused, composed of a sky component and a reflected component from external surfaces. The most advantageous conditions are when the direct component is obscured by a cloud. Direct sunlight will cause the scanned structure to have a lot of shadows and a very high contrast between the areas that are directly exposed to the sun and those that are not. With artificial lighting, unlike natural sunlight, it is possible to control the number, position, brightness and diffuse scattering of lighting sources. Nevertheless, there are situations in which it is not possible to use the potential of artificial lighting to effectively flood the resulting lighting. In the process of photogrammetric recording of construction, their combination is most often used.

4 RESULTS AND EXPERIMENT EVALUATION

In order to evaluate the impact of lighting when capturing the course of work on the construction site using 360° photogrammetry, experiment was performed. Appropriate areas (basement area with artificial lightning) inside the projects were identified where measurements with different lighting conditions. As we discussed above, interior lightning conditions are related to other processes and mostly are insufficient for work execution or even for data collection.

The impact of lighting when documenting the course of work on the construction site using 360° photogrammetry is crucial. Due to the ongoing construction, the premises of the building, especially the interior, are not sufficiently illuminated by natural light. Although the standards set requirements for lighting in works and activities at the workplace, which is also the construction itself, for the purposes of continuous collection of data on work in progress, it is necessary to focus (photograph) places where current activities do not take place and as a result are either poorly lit (e.g. for communication purposes or for reasons of possible evacuation), however, there are also areas that are not illuminated at all. In these places, it is necessary to use either a commonly available turn signal light, but in this case, we reduce the possibility of further use of the photo.

The measurement was performed with two types of cameras, Ricoh Theta V1 and Ricoh Theta Z1, in which all measurement positions were identical. At the same time, an image was taken with a Ricoh Theta Z1 camera using soft diffused light in a 360° scattering cylinder (light cylinder diameter 62mm, light cylinder height 90mm, power 755lm). So in this experiment, individual spots were captured with and without spherical 360° illumination.

The higher ISO is set in the camera, the worse ability to determine the interface between elements. According to the evaluation of values Fig. 3 describes the relation between ISO and usability of photo for either construction progress or for measurement purposes. In the chart, average values are presented.

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This experiment did not prove significant issues with particular ISO values event though the results are slightly worse using ISO 1000 and 1250.

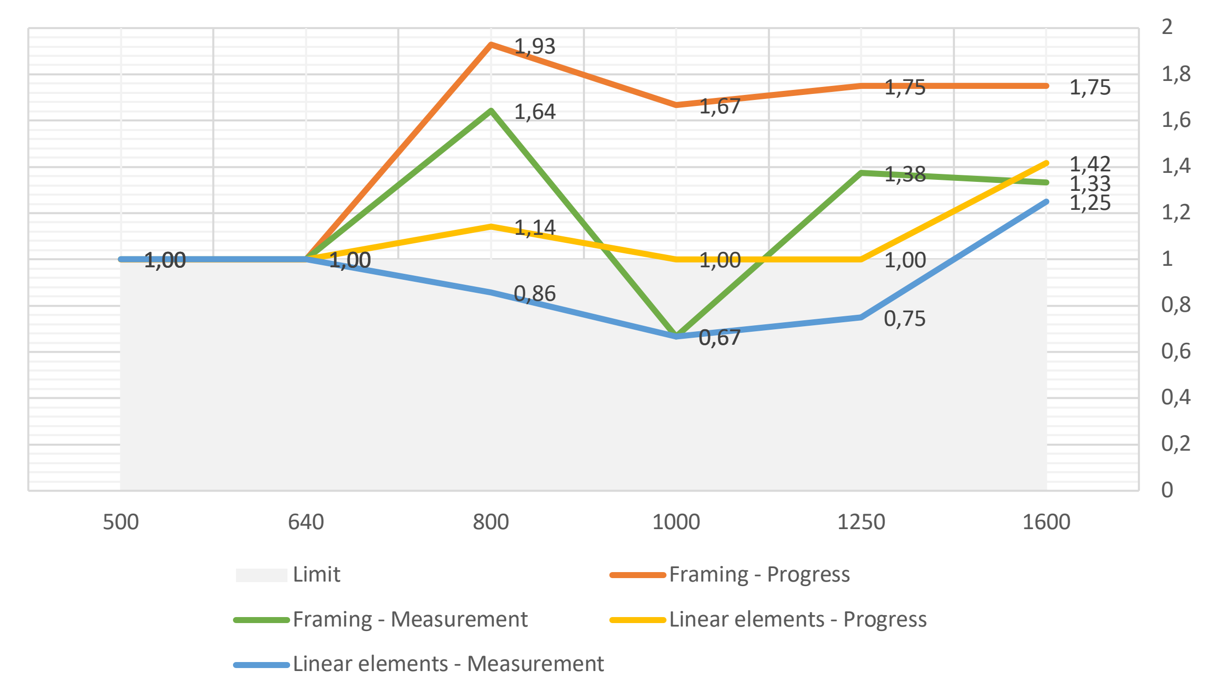

Fig. 3 Relation of ISO to the usability of the photo

4.1 Assessing the construction progress

Based on the data collected during the experiment, charts are presented. The data sets were revised from the perspective of assessing the framing construction, which are usually extensive structures and elements and the perspective of linear elements, which are usually subtle and their third dimension is dominant.

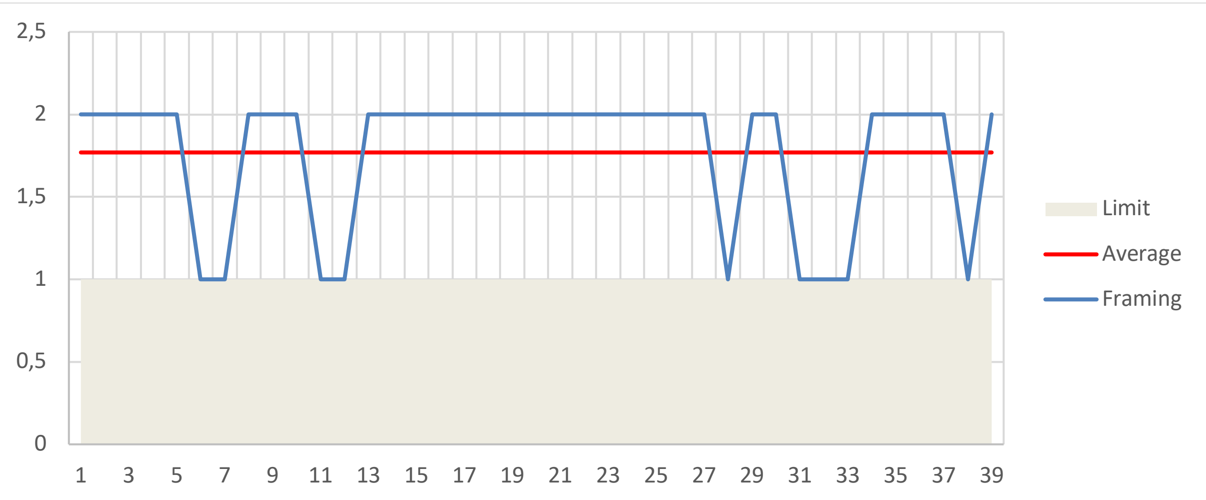

Fig. 4 Construction progress, Framing

Evaluation of individual capturing positions when assessing recognizability of progress of the framing, i.e. if the elements around are clearly recognizable from the photo in particular lightning conditions, is shown at Fig. 4. Blue line represents values (y-axis) in positions (x-axis), red line presents the average value indicating the suitability for this purpose and grey area represents the limit of measurement with

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no recognition, therefore indicating not suitability for this purpose. We can state, that in general, **any indoor lightning provides sufficient data for evaluation** even if the ISO value is higher.

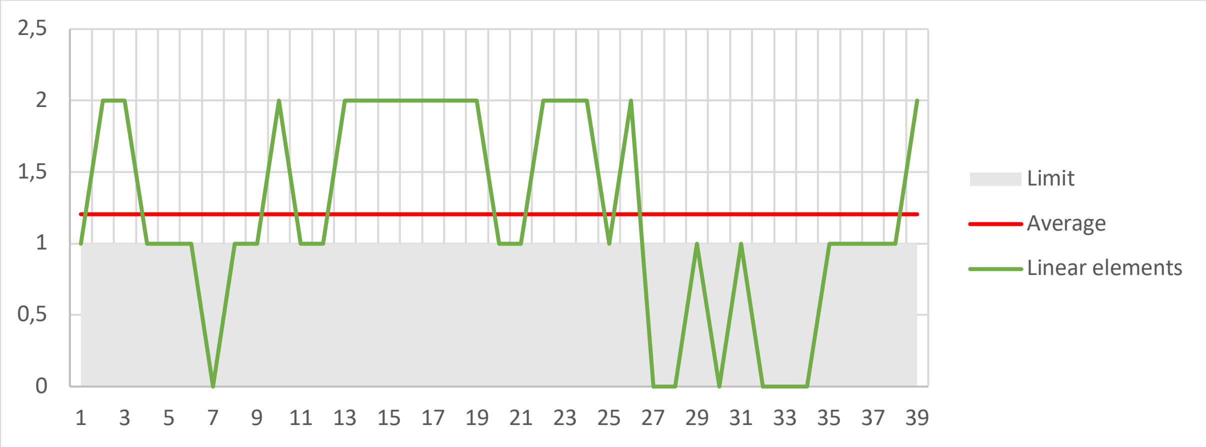

Fig. 5 Construction progress, Linear elements

Evaluation of individual capturing positions when assessing recognizability of progress of the linear elements, i.e. if the elements visible from the position are clearly recognizable from the photo in particular lightning conditions, is shown at Fig. 5. Green line represents values (y-axis) in positions (x-axis), red line presents the average value indicating the suitability for this purpose and grey area represents the limit of measurement with no recognition, therefore indicating not suitability for this purpose. We can state that from some of the photos, **linear elements are difficult to be recognized**, especially with low light positions.

4.2 Assessing the suitability for measurement

Based on the data collected during the experiment, charts are presented. The data sets were revised from the perspective of assessing the framing construction, which are usually extensive structures and elements and the perspective of linear elements, which are usually subtle and their third dimension is dominant. Evaluation is based on the ability of recognizing the interface between individual structures so that it is possible to measure distances for different purposes.

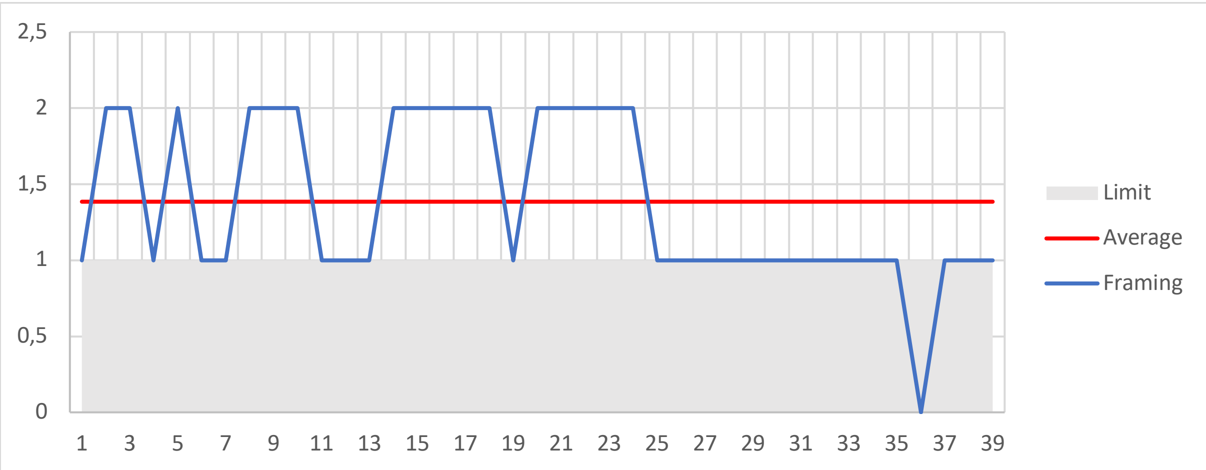

Fig. 6 Measurement suitability, Framing

Again, evaluation of individual capturing positions when assessing recognizability of progress of the framing, i.e. if the elements around are clearly recognizable from the photo in particular lightning conditions, is shown at Fig. 6**Chyba! Nebyl zadán název záložky.**. Blue line represents values (y-axis) in positions (x-axis), red line presents the average value indicating the suitability for this purpose and grey area represents the limit of measurement with no recognition, therefore indicating not suitability for this purpose. We can state, that **for the purpose of measuring the framing elements, lightning is usually sufficient**, but in some particular conditions, existing lightning of may interfere with the results.

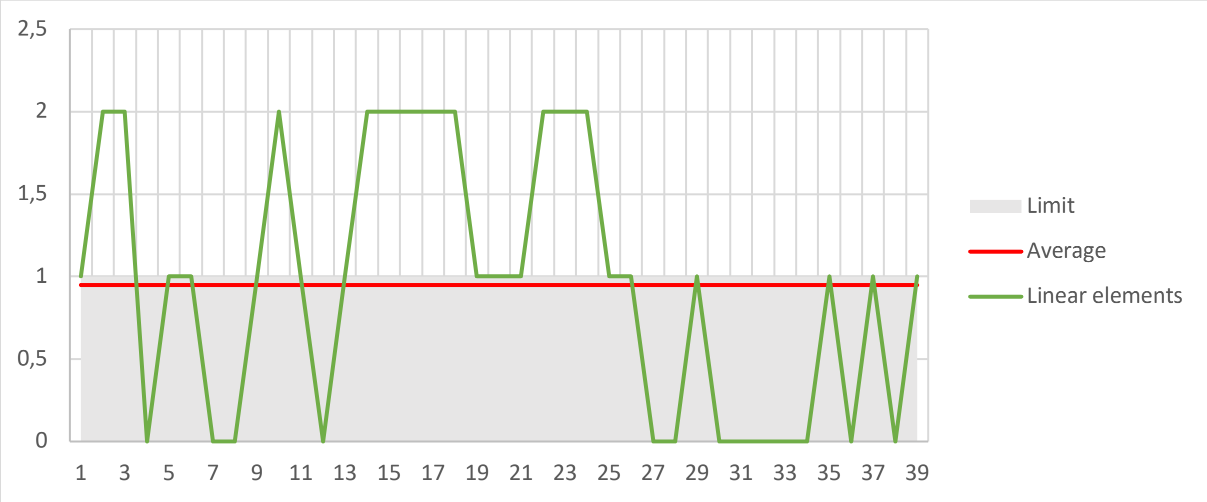

Fig. 7 Measurement suitability, Linear elements

The chart shown at Fig. 7 represents the evaluation of individual capturing positions when assessing recognizability of progress of the linear elements, i.e. if the elements around are clearly recognizable from the photo in particular lightning conditions**Chyba! Nebyl zadán název záložky.**. Blue line represents values (y-axis) in positions (x-axis), red line presents the average value indicating the suitability for this purpose and grey area represents the limit of measurement with no recognition, therefore indicating not suitability for this purpose. We can state, that **for the purpose of measuring the linear elements, lightning is usually not sufficient.**

5 DISCUSSION AND CONCLUSION

Lighting conditions on the construction site are not always ideal, especially in terms of the use of creating photographs for the purpose of documenting the construction and use in the subsequent control of development or quality.

Based on the experiment, we can state that the available lighting of the building is suitable for documenting the progress. In some cases, additional backlighting is appropriate, but it appears that where there is already existing lighting, additional light will aggravate the situation and result in poorer photo quality and recognition of the structures on it. So, for construction progress monitoring of framing, lightning is mostly irrelevant, for construction progress monitoring of linear elements, this process is more lightning dependent but in general, results are still usable. On the other hand, when the focus is to measurement, special attention needs to be put to lightning setup ensuring the good overall results, especially when the supporting light interfere with existing lightning, making the depth of the visible interface shorter.

Further investigation is needed to define the active radius of on-site positions based on certain lightning condition. The resulting methodology should than include a proposal to ensure suitable lighting conditions during shooting, which in turn will contribute not only to higher quality capturing and reduce the deviation in the creation of the model, but also to record the progress of work on site.

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