"THE SURVEYING PROCESS DURING THE CONSTRUCTION WORKS INCLUDING BIM. LATVIA EXPERIENCE"

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ABSTRACT

In a rapidly developing world, in the era of innovation, engineers and people who are somehow associated with construction can hear the word combination Building Information Modeling (BIM) more and more often. But not everyone understands the meaning of these words. This concept is developing fairly quickly but in the countries such as the UK and United States of America. Unfortunately, it is only at the stage of development and introduction in the Baltic countries. The purpose of this work is to explore, summarize and describe a small part of the Building Information Modeling process, particularly the process in which the surveyor participates. To understand if surveyors in Latvia are ready to introduce BIM.

BIM in the construction process is the future and soon large projects won't be able to get done without the BIM structure, therefore it needs to be studied and adapted in Latvian construction industry today. Those who the first discovered many aspects of BIM will become the best experts in the industry, they will lead and work in large BIM projects.

The author will illustrate the construction process, particularly the work that the surveyor will have to perform if it is a new BIM project will be. The author will describe the work of a surveyor, methods, devices, technologies. Technologies will be compared following with an explanation of how to combine these technologies. The paper will describe the actions and measurements on the author's own experience, with such tools as TPS, GNSS, laser scanners.

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BUILDING INFORMATION MODELING

Building Information Modeling/Management is the process of creating information database about construction project as well as managing, supplementing, editing this information during the full life cycle of this project. The result of the BIM process is 3D model with the information about building along with the digital description of each aspect or a description of a particular, key part of the constructed object also each element of this model can be assigned additional attributes. (EU BIM Task Group, 2016) This model is produced using available information or produced from scratch and updated on a course of construction of object. Creation of such Building Information Model of the object allows optimizing construction works, calculating the cost and life cycle of the object and also helps those who interact with this building. BIM model reduces the need to refine the design at different stages of construction and also reduces duplication of drawings for different construction disciplines. The 3D design tools take precedence over 2D drawing, each object is connected to the database and since the complete database is very large, the project can be produced quite quickly. After 3D project design cost of materials can be calculated easy and fast.

BIM in construction process gives a lot of advantages, because the basis of BIM is not only a 3D model, but also a lot of additional information that can speed up construction, reduce costs, make construction safer. All this depends on the collaboration between the project participants who make this project, as well as improve during the construction. BIM will increase productivity, improve quality, and also improve the labor market, because the company will need good specialists who have good knowledge in theory and practice in BIM, with such a BIM team it is much easier to implement the project. (Ball, 2018)

BIM IN LATVIA

In Latvia, the BIM is under the control of the *Ministry of Economics*, much depends on them. At the moment in the framework of public procurement, the *Ministry of Economics* will develop a roadmap for the implementation of Latvia’s national BIM, which will define the objectives, necessary actions and resources for the successful implementation of BIM in government procurement in Latvia. BIM in Latvia is at the initial stage of development, and I cannot say that people have not heard about BIM concept, because references to this term can be found in Latvian articles of 2011, and even earlier, but not everyone understood what it was. In 2014, the association of BIM activists “Būvkonsultants”, in order to explain to people what BIM is, developed a handbook of BIM. This book is positioned as: the first step in Latvia towards regulating BIM as a process.

Currently in Latvia exists "The Building Information System", this system includes information and documents necessary for the construction and control process, and ensures the dissemination of information between the government, control authorities and construction participants, as well as public participation in the construction process. The ideology of this system is very similar to BIM, but all information is distributed between the state and the second organization / person, so this cannot be called a fully collaboration.

The situation regarding the digitalization of the construction industry in Lithuania and Estonia is much ahead than in Latvia. It all started at the same time as in Latvia, in 2014 Lithuanian state organization was created, uniting more than ten associations operating in the construction sector, to coordinate the process of digitization of construction in Lithuania called “*Skaitmeninė statyba*” (Digital construction). (Skaitmeninė statyba, 2018) In 2015, the BIM development strategy in Lithuania was developed and approved by the government, which proposes to develop BIM from 2015 to 2020, in order to fully implement BIM in the Lithuanian construction industry.

Estonian project companies started testing the BIM software’s in 2006, and in 2008 several companies began using BIM in their work, one of these companies was the real estate company “*Riigi Kinnisvara AS*” (RKAS) the shares are 100% owned by the Republic of Estonia., which also adapted for themselves the COBIM (Finnish BIM Guide), and in 2013 COBIM was translated into Estonian. In 2016, *RKAS* developed new requirements for BIM modeling they also included the first version for the information level for data modeling. In the same year, the first Estonian BIM standard “EVS 928:2016 BIM terminology” was provided. At the moment, 17 parts are developed in this guide for Non-Residential project in Estonia, and part 16, refer to BIM. (Riigi Kinnisvara AS, 2018) Builders can now voluntarily use the BIM system, but in Estonia it is not necessary. With the time, this system will become mandatory.

SURVEYORS AND BIM

Surveying is an integral part of any construction. Geodetic works are a complex of measurements, calculations, drawings, which will ensure correct and accurate building position, as well as the construction of structural and planning elements in full compliance with the regulatory documents and geoparameter of the project.

Surveying work must be carried out by professional experts in this field. According to Europe website on regulated professions (http://ec.europa.eu) and information that contain a database of professions: Surveyor is a person who is engaged in Land surveying, cadastral surveying and also make geodetic works for construction works. This site provides information about the national law “On the Regulated Professions and the Recognition of Professional Qualifications”, which more accurately describes the profession, as well as information on how to get this profession. (European Commission, 2018)

A surveyor can and should participate in all stages of a project. Depending on the stage of the project, the surveyor, in his work may use different equipment, methods and programs for data processing.

The BIM process can be divided into stages. The first stage is “Initial data”. In the initial stage of a BIM project, the issue of creating such a project is considered. Formulate the technical project. All the necessary information is collected, such as: reviews of previous projects, spatial requirements, budget assessment, risk planning. As well as the assembly of the BIM project team and the distribution of their roles and responsibilities. At this stage, a surveyor may be needed to obtain initial data (Geospatial information) for site calculations and project development in the future. Obtaining such information can be identified by topographical survey. This is the beginning of a collaboration between a surveyor and other BIM project participants. BIM project is being developed, based on the land measurements made by the surveyor.

When the stages of creating a conceptual, detailed design, model, analysis, calculations of time and budget, along with the preparation of documentation are completed, the construction process begins. The construction process for a surveyor can be divided into three periods:

preparatory construction period, main construction period, end of construction. After the geodetic network is created, the surveyor should work with the project, the data he received from another project participant from the project manager, architect or engineer. IFC model, with a certain level of details and with the information that the surveyor needs, nothing extra. The surveyor must prepare this data for his work. The most important part of the data preparation process is the creation control points in BIM that exactly correspond to the physical points set in the field. Next step is to stakeout necessary points and construction axes. Main construction period for surveyor, includes all the work that the surveyor performs directly, already during the construction of the object. The surveyor is working to bring into nature all the basic structures of the building.

According to the results of the As-Build geodetic survey, the contractors, participants of the BIM project, receive data enabling them to adjust the work performed at any stage of construction and ensure the quality of the installation of all prefabricated structures. After construction is completed, surveyor need to make the final measurement of the finished building. Any changes that have affected the original design should be recorded. Changes can also be compared with the accepted new project, which was changed during the construction and measurement of the construction. (Pettee, 2005) The received measurements can be downloaded to the graphic BIM software and update the BIM IFC model. (Kang, Subramanian, & Faghihi, 2012)

A very important job that a surveyor performs is deformation monitoring. Deformation monitoring requires careful collection and analysis of measurements.

Geodetic measurements should be carried out to determine:

- vertical deformations of the foundations;
- horizontal deformations of the foundations;
- tilt of the building;
- deformations of individual structures and parts of the building.

Measurements made by a surveyor can be used by constructors and engineers for building analysis and calculations.

Point cloud measurements in constructions

Initial data about planned place of the BIM project can be obtained using laser scanning. Laser scanning technology is becoming more popular, and scanners are becoming cheaper and more acceptable for users. With the laser scanning technology building, place geometry can be capturing very fast, this information can be used in BIM modelling, documentation, for creating 2D plans, inspections. Laser scanners capture 3D points (X,Y,Z) in the form of point cloud. Depending on the technical parameters, the laser scanner captures all the information that can be seen from the position where it is installed, the distance that the scanner can measure can reach 1 km and scanning speed is from 10 000 points per second till 2 000 000 points per second.

Surveyors, without scanning the places for new projects, scan also old buildings, the facades of old buildings, often have very complex architecture, can be capturing only with laser scanners. A huge number of measurements allows you to get the most reliable field data about the object. Other technologies cannot provide such a number of measurements in such a short time.

Laser scanning can also be used directly at the stage of building a BIM project. Laser scanning is more often used when something is already built, because the tool does not have the ability to transfer the plan to the site. Information obtained by scanning can be compared with the BIM model to ensure that all components are installed in the right place. If any errors are found, the design may be revised so that new components can be modified during the manufacturing process instead of making costly changes on the construction site. Laser scanning can also be used to quickly assess the flatness of slabs of concrete objects, such as floors, walls, ceilings. That allows, if necessary, at the initial stage to make corrections.

The measurements of the object at different stages of construction include information about the time when was this measurement. This model can be compared with the 4D BIM model. The 4D BIM model contains information about the time, and allows the project stakeholders to see the necessary project stage on a given day, the information received from the scanner will allow make an analysis of the object, and understand whether everything is on schedule. (Tarkan, 2012) Data obtained from a laser scanner, provide information on how the project is built, how precisely the concrete parts of the building are installed, and information when this was done. With laser scanning, is possibly get information about installing mechanical, electrical and plumbing parts, these parts with a fairly complex geometry is difficult to measure by classical methods, and the scanner will help determine their exact location, and compare with the MEP part of the BIM project.

Laser scanning can be used not only during the construction of a new BIM project, but also to measure an existing building, to create BIM project for a complete reconstruction of this building. This is required because, most often, old buildings do not have drawings and documentation, or these drawings and documentation are outdated. These materials can not be used for reconstruction, especially for the manufacture of a BIM project, an IFC model, because it is impossible to avoid further errors. Such errors can be identified only at the construction/reconstruction stage, and they can cost a lot of money. In this case, it is cheaper to order a laser scan of the entire object, and to get fairly accurate information as the basis for a new BIM project and a more accurate IFC model. (Hayes & Richie, 2018)

Analysis and comparison of measurement technologies and methods

The work that a surveyor performs on a construction site is very important, because the entire process of construction can be lost from the incompetence, negligence of the surveyor himself, as well as the calibration of his instrument. Therefore, to perform such work on a construction site, only a certified person must perform this geodetic survey, and the instrument must be calibrated and have a calibration certificate, as prescribed by the law of the Republic of Latvia. Not all surveying work at a BIM construction site can be performed with one device.

TPS, GNSS, Laser Scanner, Unmanned Aerial Vehicle, provide a different range of measurement capabilities, different accuracy and functionality. Table 1. shows the possibilities of using various measuring instruments on the construction site, the table is compiled on the analysis of the above-mentioned geodetic works, the capabilities of the measuring instruments.

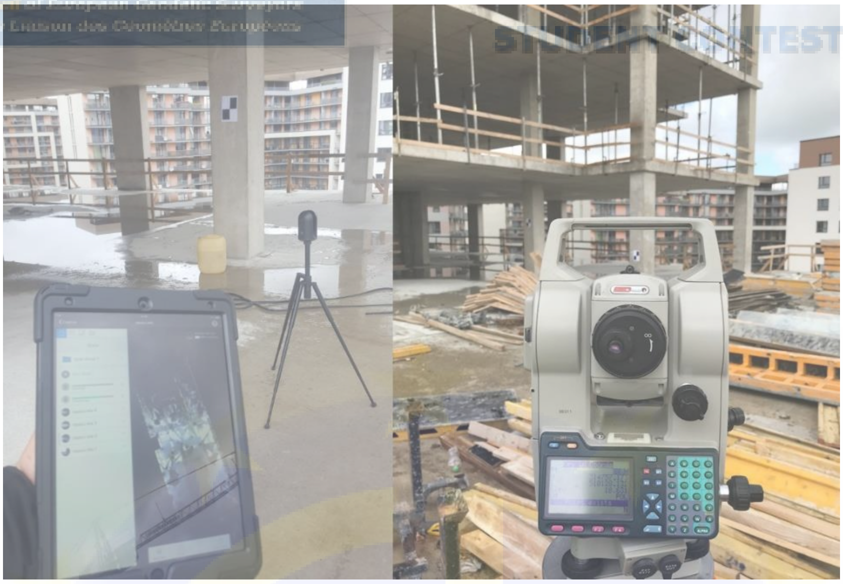
1. Table, The possibility of using surveying instruments at the construction site (Author)

Device/ Construction work	Topografic survey	Construction site network	Stakeout	As-Build Survey	Volumetric measurement	Deformation monitoring
TPS	+	+	+	+	+/-	+
GNSS	+/-	+/-	+/-	-	+/-	+/-
Laser Scanner	+/-	-	-	+	+	+
UAV	+/-	-	-	+/-	+	-

Table 1., with (+) shows which device can be fully used in mentioned building process, with (+/-), where device can be used, but the data will not be completed or need some measurements with another device, with (-), device cannot be used. Based on Table 1., Total Station, a tool that must attend any construction project. Almost all the work of a surveyor at the construction

site can be performed using this TPS, but this does not mean that the total station can perform some work faster than other device. As is known, the TPS allows measurements to be performed with fairly great accuracy, but this is not necessary for volumetric measurements, depending on the volume, it can be a very time-consuming process. GNSS can be used for topographic surveying to coordinate TPS, if there are no geodetic points near, but it is rather difficult to measure the topography with GNSS, because due to height buildings and trees, the signal may not reach the GNSS receiver, and obtaining the coordinates of the required object may be difficult. A similar situation with the geodetic network at the construction site. Laser scanner is very good for fast collecting geometric data. But with the laser scanner, it is impossible to make a geodetic network on the site, because the instrument only collects data, cannot select certain points to create base points, also not possible install the construction axis. This work can not be done also with a UAV. For topography, geodetic coordinates are needed, for a scanner and a UAV, needed to set ground points, which must be measured using TPS or GNSS. The laser scanner is very suitable for measuring the finished building, or construction at a certain stage or deformation monitoring, the data is obtained as detailed as possible, the measurement speed is high, this data is best compared with the BIM model of the project.

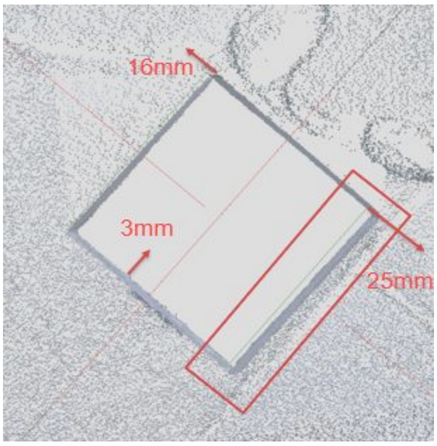
To perform productive geodetic works, 21st century surveyor must know, be able and use more technologies, be able to combine them. Performing work with more than one device will significantly increase the speed of work, the result , the amount and quality of the obtained data. The most important work is performed by the total station, because it allows you to make quite accurately, the points of the geodetic network, along which the axles will be stake-out later. During construction, when a certain part of the building has already been built, the best method for fixing the stage, measuring everything that is a laser scanner, but in order to integrate all the data into one system, special marks are required whose centers must be measured. with Total Station, for registration of coordinates, these marks.



1. Figure, Construction site measurements using TPS and Laser Scanner (Author)

As shown in the Figure 1. all necessary marks are measured using a total station (right), then the object is measured using a laser scanner (left). Coordinates are assigned using the post-processing program. With the TPS, additional measurements of some parts are carried out. Measurements with TPS can be carried out in order to see on the spot the correctness of the installation of the element, for measuring some parts that cannot be measured with a laser scanner, as well as for monitoring measurements from a laser scanner. In this case, the author of the work used TPS without the ability to graphically interface and IFC model viewer, only for coordination and marks measurement for the scanner, to measure the compliance of the project.

On the basis of such measurements, it was possible to identify the discrepancy of the column the projected drawing, as shown in the Figure 2.



2. Figure, Laser scanner measurements comparing with projected drawing (Author)

Same process for checking measurements made with a laser scanner and compare with IFC model. The data obtained using the UAV can also be combined with all the available data (laser scanner, TPS), the data obtained from the UAV will not be with the best accuracy, but for calculating the volumes, fixing the stage of construction, they will be suitable.

2. Table, Technical parameters for Surveying device (Author)

Device	**Accuracy**	**Measurement time and speed**	**Range**	**Information**	**File Size**
TPS	Angular measurements 1’’ Distance measurements 1mm + 1.5ppm (prism) 2mm + 2ppm (any surface)	1 pts./ 3 sec.	3500m (prism) 1000m (any surface)	Point coordinates, time, Lines	<5mb
GNSS	Hz 8mm + 1ppm V 15mm + 1ppm	1 pts./ 4 sec.		Point coordinates, time, Lines	<5mb
Multistation	Angular measurements 1’’ Distance measurements 1mm + 1.5ppm (prism) 2mm + 2ppm (any surface)	1 pts./ 1.5 sec. Scanning: 1000 pts./sec.	10000m (prism) 2000m (any surface) Scanning:300 m	Point coordinates, time, Lines, point colour, picture	>500mb
Terrestrial Laser Scanner	Angular accuracy 18” Range accuracy 1.0 mm + 10 ppm 3D point accuracy 1.9 mm /10 m 2.9 mm /20 m 5.3 mm /40 m	2‘000‘000 pts. / sec. 2.51 min/ one measurement	130m	Point coordinates, time, point colour, picture	>4 gb
SLAM Laser Scanner	1-3 cm	300‘000 pts. / sec.	100m	Point coordinates, time, trajectory, colour picture0	<3gb
UAV	1 cm	15 min	25 m altitude	Photo, Video, Time	<12gb

Accuracy, time of measurement, range, information received, the main parameters by which the surveyor chooses a devices. The author of this work has compiled information about the tools and parameters of these tools. Devices for analysis were those that the author himself used for measurements: TPS- *Leica TS16* with *CS20* controller, GPS- *Leica GS18* with *CS20* controller, Multistation- *Leica MS60*, Terrestrial Laser Scanner- *Leica RTC360*, SLAM Laser Scanner- *GeoSLAM ZEB-HORIZON*, UAV- *DJI MAVIC PRO*. Similar technical parameters have other newest surveying tools. The parameters shown in Table 2. showed what tool can be used for a particular joи. Using this information, it is possible to find out which device is more suitable for the task. Table 2. describes the speed with which information can be obtained and at what distance, which for some instruments makes it possible to calculate the approximate measurement time of the required object. For example, a laser scanner can measure all information around itself at 130 meters in 2.51 minutes, while measuring up to 2 million points per second with an accuracy of 5.3mm at a distance of 40 meters. Simultaneous localization and mapping (SLAM) laser scanner use a slightly different technology, this scanner allow measure in motion, scans connect automatically using a trajectory, and merging a point cloud, measuring speed much faster, it is possible to measure more than 3000 sq.m, the accuracy is not high, up to 3 cm, this device allows quickly record the progress of construction, like with the UAV, only inside the building.

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CONCLUSION

The purpose of this work is to explore, summarize and describe the surveyor work in construction process that was carrying out with Building Information Modeling. The author's own experience, working with surveying tools, the ability to work with various new technologies, collaboration with other Latvian surveyors and participation in Latvian BIM conferences helped to describe the measurement processes in construction.

The author managed to fulfill this goal, and to study and describe in detail the work of a surveyor in the construction process, using traditional measuring tools, tools that can measure fast and accurately - laser scanners and unmanned aerial vehicles, compare and analyze the work of tools and the possibility of combining technologies.

This full author work can serve as guidelines, for a surveyor who first encountered BIM at a construction site, can also help surveyors who are familiar with BIM projects already to discover something new.

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