BIM SOFTWARE AS A CONNECTOR

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INTRODUCTION

Building Information Modeling is not a new concept in the construction industry, this concept was introduced already in the 1970s. The process of transition from CAD system to BIM system is undergoing and many milestones are already behind us. Countries like Singapore, Norway, and the UK are leading the process by setting rules and examples to be followed by others. Mandatory use of BIM process is set in many countries with other countries setting deadlines. Why is it so? What is the background for all of these changes? How did we arrive in this situation? A short look back to history to understand the context of the present time is always important.

INDUSTRY AND ITS REVOLUTIONS

As a humankind, we have already experienced 3 big industrial revolutions with the fourth one happening now. The revolution of our age is digital, connected to the widespread use of the internet and digitization of almost anything. As we are bound to technology and fascinated by new ideas and inventions, the invention of the internet opened a whole new world to us, the digital world. For the first time, a revolution opens up a world that is not physical, some may even say, it is not a real world. However, it is a real world, at least a part of it. And even if it started as a very distant and defined world, easily distinguishable from our real world, the physical and digital realities are merging in the Industry 4.0. Before I dive deeper in explaining the concept, I will just briefly summarize the 3 previous revolutions.

The first industrial revolution originated in the United Kingdom in the 18th century. The main invention that transformed the society was the steam engine. With that was also connected a massive extraction of coal. This new energy helped to accelerate the economy and speed up the railroad manufacturing process, and the construction process has been mechanized.

Next, the second industrial revolution came in the 19th century, and the inventions of the combustion engine, electricity, telegraph and growing railroad networks, gas and water supply, and sewage systems were the main advancements. From the architectural point of interest, raising interest in steel and its use in architecture has allowed cities to start to grow higher. Thanks to the improvement in the mass production, in the second period of the second industrial revolution, the invention of the automobile became more accessible for people with the popular Ford Motel T, starting production 1908.

The beginning of the third industrial revolution or rather “digital revolution” dates to the second half of the 20th century. The biggest changes were brought by the new technologies, the rise of electronics and computers, robots and chips, first programmable logic controllers, etc.. A new energy source was discovered in the nuclear energy. The mass production has been automated in many areas, which allows to speed up the production process even more.

THE CONCEPT OF INDUSTRY 4.0

To be able to claim what is a revolution and what is not, what is important, what is an evolutionary step, and what is a revolutionary jump, we need to see the impact of the changes made on society. To be able to see clearly, we need to see things from a perspective, we need to step out. This kind of perspective is brought to us only by time or visionary imagination. In this visionary imaginative way, many people believe (me including), that we are living the fourth revolution already, that we are in the actual process of revolutionary change. However, the scale of the changes is yet hard to guess or predict.

In short, the 4th industrial revolution should be a successor of the 3rd one. If we look back to the relations of the previous revolutions, there was always more or less one century from the start of the previous one to start of the next one. This time, it would be different. The term Industry 4.0 was introduced in German government strategy for computerization of manufacturing in 2011. Since then, the principles of Industry 4.0 (I4.0) have been established, so now we know what we should expect in the near future. [Fig. 1]

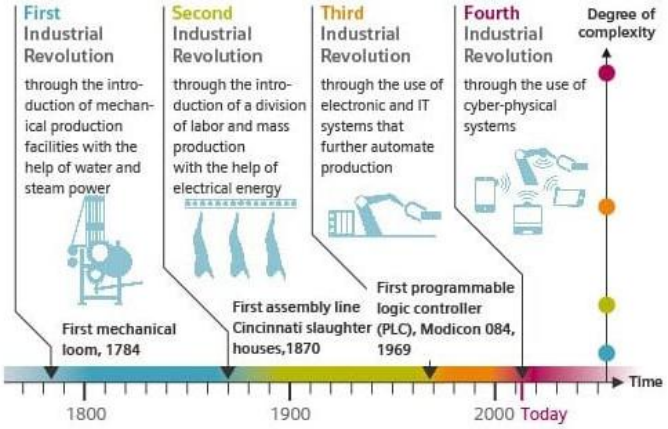

Fig. 1: From Industry 1.0 to 4.0 (DFKI, 2011)

One of the principles and a base for all changes is the internet. Even though we already know the concept of the Internet for decades, its importance is still growing and we can see already, that the primary precursor network, the ARPANET, initially served as a backbone for the interconnection of regional academic and military networks in the 1970s and todays global system of interconnected computer networks are two very different things with really different impacts on common people. As the internet reminds more of a human brain than anything else we could compare it to, we question, where is the limit of this artificial "superbrain". I4.0 tries to imagine a new world that takes advantage of this "superbrain" with keywords and concepts like Big Data, Internet of Things, Augmented Reality, Cloud Computing, etc. [Fig. 2]

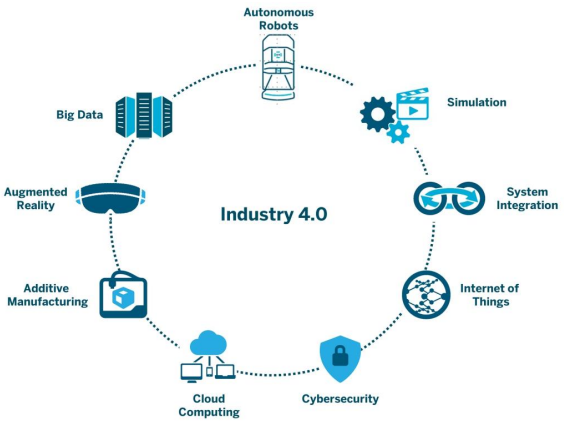

Fig. 2: Parts and keywords of I4.0

DIGITAL TWIN

What are the possibilities for construction industry in I4.0? Which technologies can be of greater benefit for builders, architects, and clients?

One of the new terms brought by the world of I4.0 is Digital Twin. Digital Twins could be defined as "*...the virtual representation of a physical object or system across its life cycle. It uses real-time data and other sources to enable learning, reasoning, and dynamically recalibrating for improved decision making." (IBM, 2020)* What it means is reality? That Digital Twin is a virtual copy of a real thing that allows us to simulate its behaviour over time or in interaction with other digital twins or some set of conditions. How does it relate to the construction industry?

Imagine you are an architect and your task is to design a skyscraper in a plot in Manhattan, New York. To create the best design for your plot, you should know your building plot conditions. That includes the knowledge of the neighborhood and its buildings, orientation towards the cardinal directions, plot streetscapes, prevailing winds, traffic intensity, and many more. The more information you are able to collect, the better your design could reflect on the real situation and that decreases the possibility of making a big design mistake.

For example, the designers of a skyscraper shaped in plan as a triangle, built next to the river, did not calculate the wind intensity at the facade. Since the design of the building did not reflect on the winds, windows on the facade at a higher floor were too big for the wind intensity and as soon as they were opened, they have been blown away. They had to develop new windows that could withstand the pressure and on parts of the facade they even changed the windows to fixed glass with an artificial ventilation system.

Now imagine that we have a virtual replica of the city that has all information. Not only it would help in the design process, but it would create a whole new world of possibilities in the city management as well as in the facility management of each individual building.

NEW POSSIBILITIES

If we imagine the digital twin concept not used only for separate objects but rather for a system of objects, we can imagine a scale of a building and then an even higher systems - urban blocks or a whole city. This allows for new perspectives and possibilities.

Digital twin of a city is a part of the smart city strategy. The goal is to create a virtual model of the city, a replica, with a real-time data of urban infrastructure, buildings, cars, and people. This model would then allow for better planning (for example, planning of public transport according to real data of people commuting throughout the week), simulation (for example, simulations of rain runoff by permeable and non-permeable soils and surfaces in cities) and management (for example real-time curb parking system or real time traffic management).

To be able to test or simulate equals to being able to predict possible outcomes or mistakes and hence to save time, manpower, and money. In this way, we are able not only to create a better environment in cities for its inhabitants, but also be budget friendly.

PRICE OF THE EVOLUTION – DATA

All of this comes with a price, a price we are already paying, mostly unknowingly or unwillingly. What feeds this system is data. CCTV everywhere is not necessary as we are all carrying around our allmighty devices, smartphones. By sharing a photo on Instagram, tweeting on Twitter, or attending an event on Facebook, we are giving away data that we no longer own. Tech giants like Facebook and Google create profiles of us, filled with data from trivial ones that we fill in as we sign up as gender, age, address, to a more complex ones like political preferences. This data is then being sold to companies willing to pay for it. However, not only big tech companies collect data, once you install an app for public transport in a city, mobile travel guide or a digital city card, your data may be collected for future development of a city.

To create a truly autonomous city that would react to its own needs, sensors are necessary. This may not mean that we all are going to follow the example of China with its massive CCTV surveillance system, but it may be a step closer. For example, in the US, there are several companies right now that are testing a curb parking city management system. This system works with a set of cameras that are monitoring the neighbourhood curbs and send a signal to an interconnected system,

whatever there is a free parking spot or not, and if not, the system will navigate towards the closest one.

COMING BACK TO BIM

Thus how does this all relate to BIM? As mentioned in the introduction, BIM is not a new concept, but it is a platform that allows for new concepts to grow. In contrary to CAD systems that are more or less set, with its possibilities and limits, BIM systems are still developing and have room to grow further. If we imagine CAD system as an old house with a fixed plan, BIM system would be an open plan building that is flexible in use and even expands beyond the limits with new extensions.

BIM system fits in the before-mentioned futuristic concepts and at the moment, there is no successor in sight that could shake the position of BIM. In the age of information is the answer of building industry Building Information Modeling.

ARCHITECTURE OF A BIM SOFTWARE

In the whole process of modeling, a BIM model is the key component the main BIM software that serves as a connector. It connects all inputs from different professions from a structural model, architectural model, HVAC model, MEP model, and others. This interconnected model is called the coordination model and serves for the construction as a digital template for the real building. For on-site revision, tablets with AR can be used. Such technology is already here and available the problem is in a slow process of adoption by the construction industry. Change of this scale requires not only changes in the modeling process but also the education of building foremen, so they are able to cope with the new workflow and this technology delivers faster and better results with less mistakes than the previous way of work.

Coordination model has a lot of possible inputs and many outputs, the keyword here would be interoperability. Since there is no universal “one solution for all”, the main BIM software should be able to read as much different data types as possible, same for the export. This allows for a market of plugins and 3rd party software to evolve. Furthermore it can make the work flow easier, less repetitive (if you can use one model for structure analysis, energy simulation, and rendering, it decreases the amount of work, therefore the time spent on a project and the budget for man hours of work decreases. In the next section, we will try to go through the possible inputs and imports for the main BIM software to showcase what can be put in the “open plan”.

POSSIBLE INPUTS FOR A BIM SOFTWARE [FIG. 3]

- MANUAL CREATION

The most straight-forward type of input into a BIM software is manual creation inside the software. Main design tools allow us to create basic elements of a building such as walls, slabs, roofs, doors, and windows, etc. Each element has its own unique ID and its parameters. These elements are parametric, that means that the parameters are not set as a given value, but we are able to set values for all parameters. There are different types of parameters, from the basic geometric ones (for example, height of a window, width of a door, or depth of a wall) to the more complex one (color of a frame of the window, type of door leaf or materials of a sandwich wall) up to the special one (fire resistancy of a door, U-value of a window or R-value of a wall). There is also the possibility to create your own parameters or classification system (for example, in a big project with multiple contractors, we can create a parameter with a list of contractors and connect a contractor to an object).

- 2D GEOMETRY INPUT WITH INTERACTIVE INFORMATION

Here belong all CAD type data, but also .pdf files and different file formats containing 2D vector information that can be read by a BIM software and exploded into lines, polylines, and fills. Information contained in these files includes layers or groups, this allows for an effective filter. CAD files are the most common used inputs, since the transition from CAD to BIM is still in the process and many contractors are still working in CAD systems and in many fields, it may still be easier to draw a line in AutoCAD than to model the real thing in BIM models.

- 2D (GEOMETRY) INPUTS WITH NONINTERACTIVE INFORMATION

Scans, photos, pictures, hand-drawn schemes, etc. are what we can call 2D (geometry) input. I left the word geometry here, because often it can be a scan or a photo of a plan or a detail, but this would carry no information within that can be used or read by a BIM software. That means that it serves only as a reference and needs still to be manually modeled in BIM software. To have such a reference is still valuable, since we can model everything, if we know the right scale.

- 3D GEOMETRY INPUT - INFORMATION MODEL PARTS - OPEN BIM

There is one preferred way of creating a BIM model that serves as a "holy grail" of BIM and that is an interconnected cloud model that is shared in real-time with the participants. This model allows all contractors to work straight within the coordination model or link their parts of model. These models would be ideally in interchangeable format .ifc. This file format carries BIM data, cross platforms, and cross software. It was developed as a part of the open BIM strategy that promotes interoperability. This format allows even to transfer BIM models from a BIM software to a BIM software. Even though this file format still has a lot of problems and bugs and the development is not directly pushed by any BIM software, it evolved into a BIM standard exchange format.

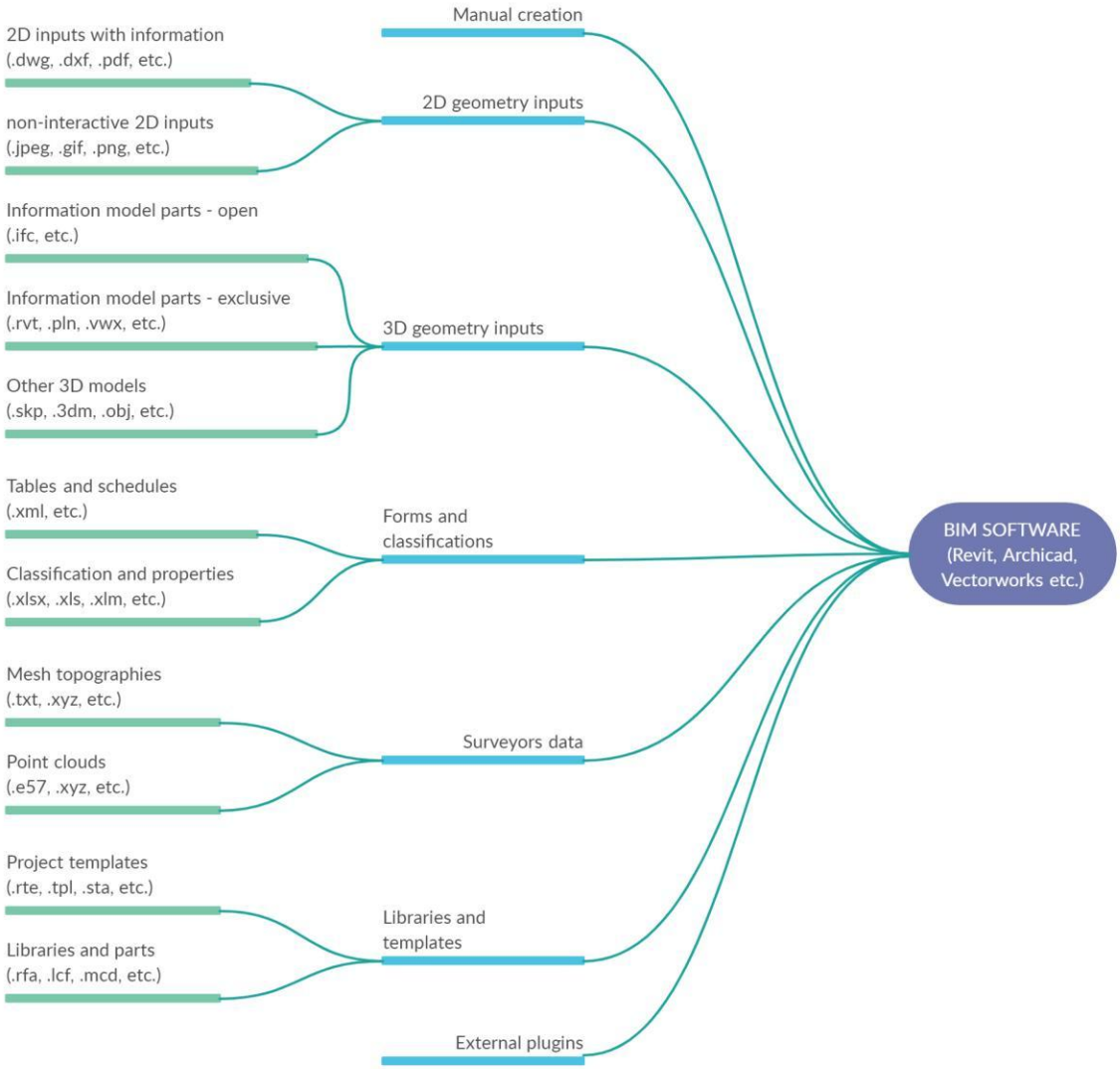

Fig. 3: Scheme of different types of data inputs into a BIM software (Majna, 2021)

- 3D GEOMETRY INPUT - INFORMATION MODEL PARTS - BIM SOFTWARE EXCLUSIVE

By BIM software exclusive 3D input, we can understand the standard file formats of BIM software (.rvt for Autodesk Revit, .pln for Archicad, and .vwx for Vectorworks). These files can carry unbroken information that does not need to be translated through translators of different file formats and are thus the most suitable files for the coordination model. Since they are native files, all objects and attributes are classified properly.

- 3D GEOMETRY INPUT - OTHER 3D MODELS

BIM software often needs to import 3D data from models created in external software like SketchUp, Rhinoceros, 3ds Max, Blender, and others. These are used by architectural studios because of their freedom in the creative process. For a parametric architecture design, industry leaders Grasshopper and Dynamo have already found a solution and are able to connect to a BIM software (Dynamo with Revit and Grasshopper through a plugin with Archicad). Non-BIM 3D models have limited possibilities in BIM software, both from a modeling or editing point of view, and they cannot carry as many information as native design tools (these models do not have specific hotspots to edit the object in 3D and do not have the parameters native objects have).

- FORMS AND CLASSIFICATIONS - TABLES AND SCHEDULES

Probably an even bigger and more important part of BIM software is the ability to link objects with the model, organize them, and create tables and schedules. These can be not only generated but also imported in the form of .xml file.

- FORMS AND CLASSIFICATION - CLASSIFICATION AND PROPERTIES

As mentioned before, objects can be classified and they have properties. Special classification systems and properties created for a project can be exported and then imported in a new one project, if these are needed. These are shared in the form of .xlsx files or .xlm files and can be edited not only in BIM software but also in MS Excel.

- SURVEYORS DATA - MESH TOPOGRAPHY

Different types of data that can be imported in a BIM software are mesh topographies. In the form of .txt file or .xyz file, we are importing a text file that can be automatically translated to a model of terrain. This allows us to form exact topographies of the site, what is important for a right placing of a building.

- SURVEYORS DATA - POINT CLOUDS

A point cloud is a set of data points in space. Each point has its set of X, Y, and Z coordinates. These can be connected in a software to surfaces. If they are not connected, these files can be very heavy and they can significantly slow down the BIM model. Point clouds are imported in a file format .e57 or .xyz and serve mostly as a base for modeling the surrounding area positions of buildings and trees.

- LIBRARIES AND TEMPLATES - PROJECT TEMPLATE

There are many ways in which we can save time and be more effective by using BIM software. One of the ways is a creation of a template file. In this file, we can have all saved favorites, own build libraries loaded, the layout structure used for handing out the project, or the design style used by the company. This can significantly reduce the time of doing repetitive work.

- LIBRARIES AND TEMPLATES - LIBRARIES AND PARTS

How can we improve the library of objects in a BIM software? Well, there are two main directions, either we are going to download a single object by object or we can download whole library of objects. The source of such files can be a specialized website like BIMobject.com, which focuses on providing real objects modeled and provided by companies, or you can search for specific libraries of elements from one company.

- EXTERNAL PLUGINS

External plugins are a different kind of input in BIM software. Unlike the previously mentioned points, plugins can expand the main BIM software, so technically you could say that it is not a data input but rather a data connection. There are different types of plugins, some are available for multiple BIM software (for example, Enscape, software for creating visualisations that has a real-time rendering preview) and others are software exclusive (PARAM-O, Archicad exclusive node-based editor and 3D live preview). External plugins need to be installed, so they cannot are different from other types of input in this way.

CONCLUSION

In this short article is introduced a background for the claim that BIM is the present and future standard of the building industry. This article walks us through the history and reminds of the times before the current revolution, that is undergoing, transformation of the world to Industry 4.0. After a short description of the current situation, the focus moves to a digital twin concept, a part of the I4.0 scheme. By explaining the importance of digital twins, from the scale of an object up to the scale of digital twin cities, we are slowly coming back to BIM. Stating the importance of a transition from a CAD workflow to a BIM workflow, not only for obvious economical reasons, but also for the possibility of keeping up with the development of the industry. Since BIM is the only solution for the questions already on the table and for some time will cover also questions not yet formulated, our focus is then shifted towards a BIM software that works as a connector. In this article, we do not focus on a description of the BIM process as such, but rather on possible inputs for a BIM software and a coordination model. We have classified the inputs by data types, a different approach could be classification by profession or contractor. The data type classification divides the possible inputs more generally and the scale of the project does not matter in this division, which would be not true for the other division. By briefly introducing each of the possible data type inputs, we set a ground for the analysis of possible data type outputs, what will be the focus of the next chapter.

GLOSSARY:

BIM *- BIM or Building Information Modelling is a process for creating and managing information on a construction project across the project lifecycle. One of the key outputs of this process is the Building Information Model, the digital description of every aspect of the built asset. This model draws on information assembled collaboratively and updated at key stages of a project. Creating a digital Building Information Model enables those who interact with the building to optimize their actions, resulting in a greater whole life value for the asset.*

HVAC *- Heating, ventilation, and air conditioning (HVAC) is the technology of indoor and vehicular environmental comfort. Its goal is to provide thermal comfort and acceptable indoor air quality. "Refrigeration" is sometimes added to the field's abbreviation, as HVAC&R or HVACR or "ventilation" is dropped, as in HACR (as in the designation of HACR-rated circuit breakers).*

AR *- Augmented reality is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information*

ID *- Identity*

IFC *- Industry Foundation Classes is a data model intended to describe architectural, building, and construction industry data. It is a platform neutral, open file format specification that is not controlled by a single vendor or a group of vendors.*

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