New BIM Approach Connecting Discipline Designers to Common Platform

Focus on construction design

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***Abstract*—Architectural design is a multivariate, complex process. Traditional drawing methods have been almost completely replaced by the digital approach and BIM is becoming more widespread. The design process is a fragmented process, especially for larger buildings, it is possible that up to 100-150 people are working on a project. This article shows the different disciplines, their relationships, and outlines a new approach to facilitating collaboration. Effective communication is a key to high quality planning. During this research the work of the construction designers were examined, and a new method was developed for the further processing of the information content of multi-layered structure documentation. In this method, the information is stored structured in a VBA programmed Excel providing a database, thus information can be processed immediately and loss free. This paper introduces the concept of Dynamic Information Raise, which is the presented developed method. The content of workpieces created by construction designers are stored in a structured system and linked the data into the BIM model in an automated way. Applying this method, different sections of work can be directly linked to the related discipline software. These expertise disciplines do mainly textual work, they do not build the 3D model, so they use BIM to a small extent. This method was tested on three ongoing design projects and the investigations showed significant time savings and greater accuracy.**

Keywords*—*BIM collaboration; Dynamic Information Raise; design workflow; construction data flow

I. Introduction

The advent of digitalization, computers, machines, and the internet has significantly transformed various industries, including the architecture, engineering and construction (AEC) sector. During architectural design, digitization has also significantly transformed workflows. Machine processing came to the fore and hand drawing came to background, perhaps it remained only during conceptual design. Architectural design is a very complex area. The final building can be designed as a result of the collaboration of many different disciplines, as it is presented in Fig. 1. Over time, these areas have become so fragmented, already in the education system. Different, separated faculties are in the university system and professionals are organized into companies by typical disciplines. All experts are rarely within a company. Building Information Modelling (BIM) methodology [1] [2] [3] improved effective collaboration and communication between experts. The principle of modeling and information assignment has further strengthened digital reform in the field.

II. Different disciplines in building design

During the architectural design, the final building design and its details are formed from the cooperation of many experts and disciplines [4] [5]. Although the expertise of each designer is required, there are larger design units that play a greater role in shaping the building. One of these is the architectural team, who need to be in touch with almost every other expert. Communication has thus become a major factor in successful building design. The BIM method was a kind of solution for this, because building the same model, or at least communicating on model basis, makes it easier to transfer information related to the given elements. The most common uses of BIM in architectural design are the following [6]:

- visualizations,
- change management,

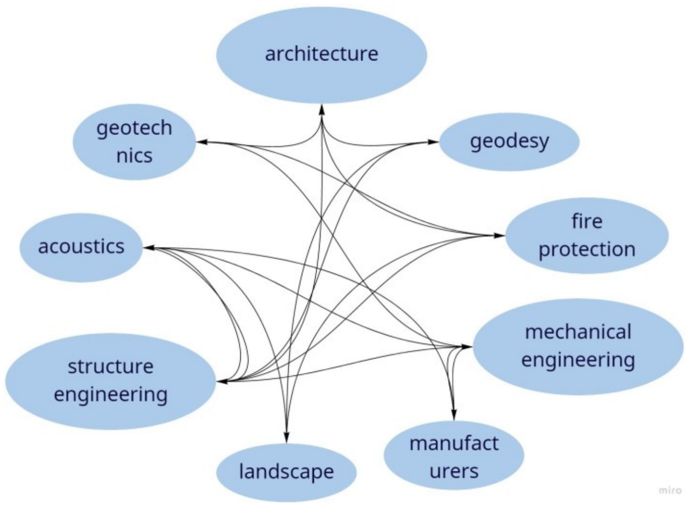

Fig. 1. Several disciplines in connections in architectural design [2]

- code checking,
- clash detection,
- fabrication,
- communication and collaboration,
- time and cost management,
- energetic and ecological design of green buildings,
- facilities management.

The most used areas of BIM clearly affect units with 3D elements. At the same time, design is a holistic workflow in which many smaller units, even written tasks are relevant. To improve communication. The interconnected data network of disciplines where the related data can be updated and processed in an automated way. This approach provides an opportunity for all participants in the design to join the information-based processing and thus experience its positive benefits as well.

III. Possibilities of connecting different disciplines

The essence of BIM is joint model building, but due to the small subtasks of the disciplines, not everyone is involved in the actual model information upload. It would include all disciplines to the model-based information content. In the following, a couple of possible areas and disciplines will be examined whose work can join the holistic unit of BIM with a new approach.

A. Multi-layered structures and performance data in structural sizing

During the multi-layered structure design, the requirements for each planned building material must be set out in the multi-layered structure documentation. The weight loads of the designed materials appear as input data in the structural analysis and sizing. The specific weight (kg/m^3) is usually available for all materials, by specifying the thicknesses of the individual layer components, the specific weight (kN/m^2) of each layer and the structure can be calculated, so the self-weight of the structure (Fig. 2) can be calculated automatically. The static dimensioning practice always rounds up the specific loads of each layer to half a kN/m^2 load for safety reasons, then applies the resulting loads to each structure, and where a smaller load is surrounded by a larger weight, the smaller area will be designed for the bigger load. If the data needed for the calculations could be automatically loaded from the database, there would be no need to recalculate the weight data of each layer in case of any changes. Service loads from usage (Fig. 3) are also building characteristics that depend on the functions of the rooms, which is a property of the zones. This data is also included in the multi-layered structure documentation, all slabs are listed there with all layered structural units, so in case of database-based design, automated load loading would be possible.

B. Multi-layered structures and performance data in energy calculation

The heat transfer coefficient (U value) depends primarily on the thermal conductivity coefficients of the designed materials (λ value). This value is usually recorded by the construction designer in both the multi-layered structure documentation and the performance specification. If these values were managed systematically in a database, mechanical engineers would be able to import the data from there and perform the energy calculations in minutes. The energy compliance of the designed structures is calculated and checked by several disciplines. Construction designers assemble the multi-layered structures to meet the relevant energy requirements, the heat transfer coefficient values. The energy calculation of the whole building and the required certification are carried by a building energy certifier, who is usually an architect or mechanical engineer. The certification also requires the documentation of the quality of the external boundary structures. During the energy certification, data recording takes about a third of the time, which could be significantly reduced by automations. Mechanical engineers also calculate the heat transfer coefficients of the structures as input data when calculating the heat losses and gains of the building envelope, which is essential for the dimensioning of building services systems (heating, cooling). Calculations related to building energy can be performed as a result of well-defined, parameterized equations. Some software (e.g.

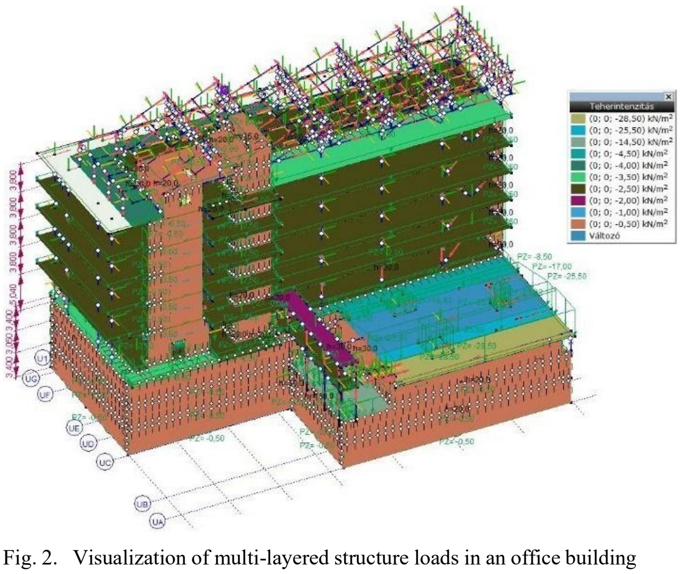

Fig. 2. Visualization of multi-layered structure loads in an office building

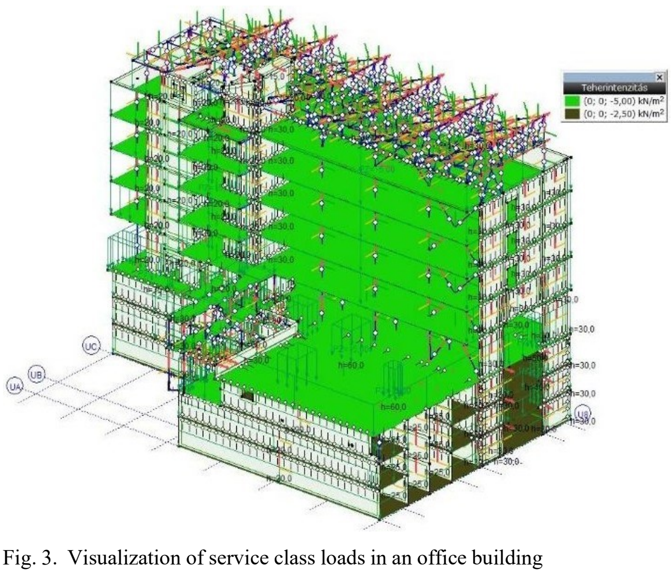

Fig. 3. Visualization of service class loads in an office building

WinWatt, Auricon in Hungary) includes these calculation methods, and after recording the input data, the process is almost completely automated. It is important to see that the input data is derived from the multi-layered structure documentation, so using the appropriate software-compatible data format would make the calculations much easier to perform after scanning, and it would also be easier to track changes.

C. Multi-layered structures and performance data in the design of acoustic comfort

One of the main tasks of an acoustician expert is to determine the sound insulation requirements: to list all the different function-function pairs in the building that occur, and be able to disturb each other, in a table and assign the weighted sound reduction index (R_w) and weighted normalized impact sound pressure level ($L_{n,w}$) requirement values according to the applicable standards to them [7]. This is typically defined in a textual section, as it is presented with an example in Table I.

According to the BIM approach, the processing of these values into a structured system, even in an Excel, would provide an opportunity to link the model with the room seals. This would allow not only the loading of the data, but also the verification. For example, a graphic override function could be used to assign a color to walls or model elements that do not meet the expected values.

D. Multi-layered structures and performance data in other design tasks

The possibilities of BIM collaboration can be further classified by considering how many administrative, text-creating tasks are and how wide the relationship system of these data is. Such areas may be the building physical design, the building acoustics (both sound insulation and room acoustics) [8], the building technology design (both mechanical and electrical), or the border of the two areas mentioned above, the interior comfort design features and properties [9], or the increasingly important environmental aspects also, built-in energy and CO_2 emission calculations. And it is obvious that the BIM approach also has many possibilities for more efficient and accurate calculation of the quantity and cost of building materials, a topic that will be really significant during the construction phase.

TABLE I. SAMPLE TABLE OF ACOUSTIC REQUIREMENTS

Connected zones	Noisy room	Room to be protected against noise	Requirements		
			R'_w+C (dB)	R_w+C (dB)	$L'_{n,w}$ (dB)
room belonging to an office unit	office	adjacent office (horizontal)	37	-	55
	office	lecture hall, meeting room (horizontal)	42	-	55
	meeting room	adjoining office if there is a door in the wall	30	-	-
	bathroom, toilet, kitchenette	adjacent office (horizontal)	42	-	-

IV. Introduction of DIR approach to construction design

The construction designer is usually a specialized architect who specializes in the design of building structures and/or construction plans and has extensive experience in the field. A construction designer is not a civil engineer who designs load-bearing structures. It is important that such a specialist construction designer is not involved in every project. For smaller projects, this task is usually performed by the architect team. However, for larger projects, the construction designer may not be a single person, but a team with different areas of competence such as energy, building insulation, acoustics, fire protection, and so on. Construction design tasks include solutions and parts that affect the work of many other disciplines. These are the following:

- preparation of multi-layered structures documentation, which contains the list of the materials occurring in the building and also contains each material thickness with the expected performance characteristics;
- detail drawings about the complicated sections and floor plans, design of the connection of the materials and the additional technical elements;
- definition of performance specifications, which contain the properties of applied materials, structures, and the expected properties (performance characteristics) which determine the range of possible products.

Quantitative capability has long been a feature of design softwares, but unfortunately there is still a lack of linking layer orders and model elements and attaching performance characteristics to materials of multi-layered structures. If this data is available in a structured system, it can be easily combined with quantitative data from the architectural BIM model. If there is a parameter that clearly identifies the elements in both systems (such as the multi-layered structure unit code), then by exporting the quality data from the model, the data can already be linked based on the key data. The result will be better, more accurate quantity statements.

The principle of a possible solution for uploading information to the BIM system is as follows (Fig. 4). The model elements must be set one by one to determine exactly what material it consists of, since the right quantities can only be extracted after the right information has been uploaded. It is

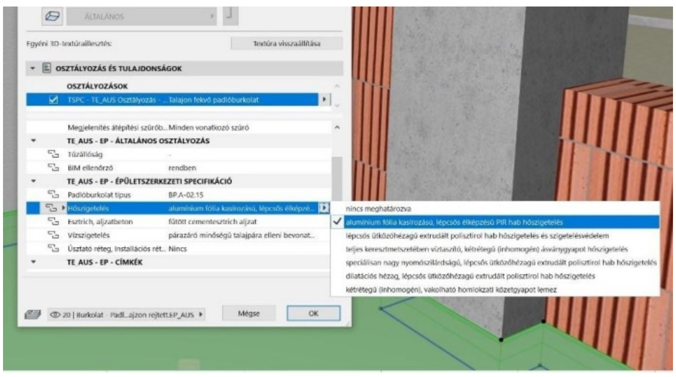

Fig. 4. Building material information content setting in the model using classifications in ArchCAD software environment

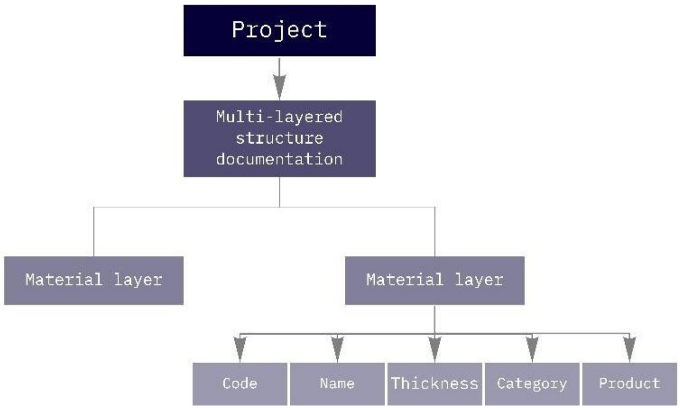

Fig. 6. Project hierarchy in the multi-layered structure creator

possible to set these values in the design program as a material type or even as a unique property value. However, each model unit (wall, slab, roof, etc.) must be assigned the appropriate value individually. This is an extremely time consuming task, due to its monotony and quantity, there is a high potential for error in human processing. All the necessary information available in the multi-layered structure documentation, so if it were database-based, it would be easy to assign it to the appropriate model element [10] [11].

Although the aforementioned method works, for each change many model information must be changed manually. This is time consuming, adds an extra error factor to the design and is not 100% reliable. Therefore, a new method was developed for this problem which is an Excel-based solution and it was tested on living projects. This method is called Dynamic Information Raise (DIR). The goal was to make the multi-layered structure data in a systematic form and connect them to the model. VBA (Visual Basic for Applications) can be used to control layered units with programmed buttons.

The architecture of the multi-layered structure documentation was examined to explore its information system for developing a structured form. The data of multi-layered structures are structured in project according to a hierarchy, which is presented in Fig. 5.

Multi-layered structure units can be assigned to a project, to each unit building materials can be added with expected requirement values and properties. The structure of Excel has developed along this principle. Figure 6 shows the formed multi-layered structure creator. The red worksheet contains instructions for use. Green worksheets contain background information that is necessary for operation, such as project name, project code, coding system and so on. The orange sheet is a collection of building materials used in the project arranged in groups. The multi-layered structures must be created on the blue tab. The general rule of “program” is that only the blue back colored interfaces can be edited. The surface consists of the following units:

1. assistant sheet (project info, coding structure, etc.)
2. multi-layered structure writing interface
3. material store (divided by structural functions)
4. unique code for a multi-layered structure unit
5. multi-layered structure unit name
6. material thickness
7. material category
8. exact material name
9. exact material with important characteristics
10. example material product
11. control buttons: create a new line, create a new multi-layered structure unit, copy a multi-layered structure, delete line, delete a multi-layered structure, delete blank lines, listing, creating a navigator.

The construction designer fixes the building materials related to the project on the material store tabs, with its all properties. This acts as a project product database, which will be available on the multi-layered structures interface. On the multi-layered structure writing interface, the designer can create individual units. By selecting the appropriate materials from the material store and then assigning thickness. A multi-layered structure unit is created this way. These can be assigned unique

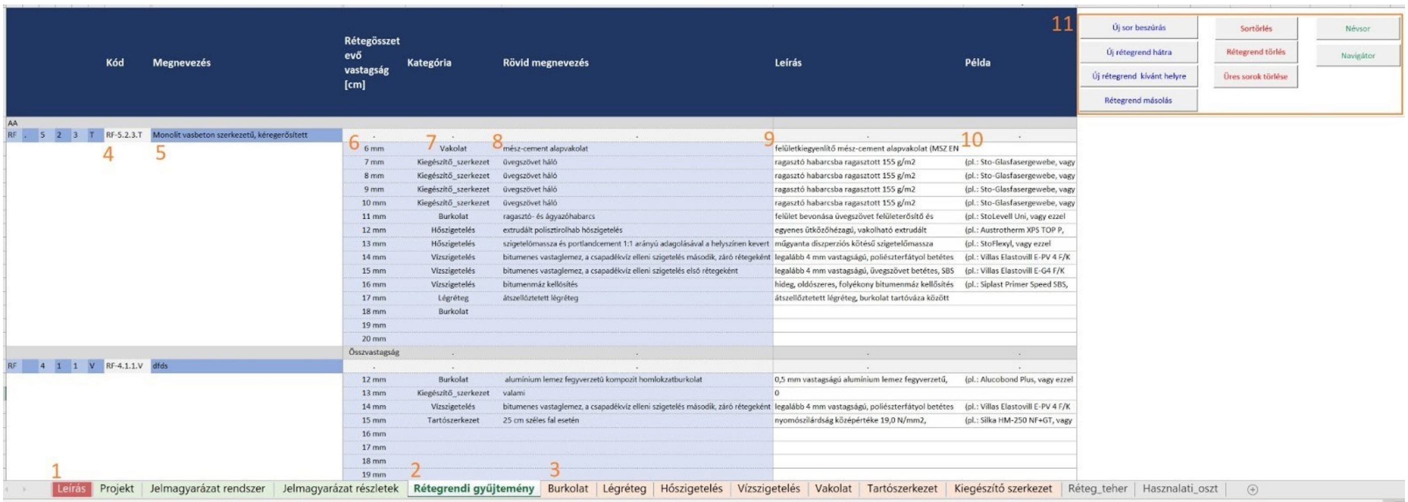

Fig. 5. Excel development for multi-layered structure documentation

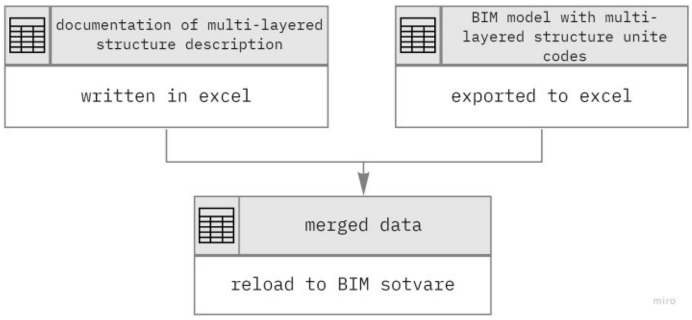

Fig. 7. Concept of building material information loading into the model

codes and names. This code is used to identify individual units. Architect designers also need to include this in the model's composite structure. It is possible to add this value either when creating a multi-layered structure or at the element level, clear code identification is important. This value is used to connect the two systems (model and description). To load the building material information into the model, it is possible to follow the principle presented in Fig. 7.

The multi-layered structure data created with this method can be linked by saving the unique code assigned to the elements with the correct geometry created in the model file. Based on the unique code, the Excel containing model element data with the "vlookup" function can find and link the material properties from the multi-layered structure documentation. The data file created in this way can be loaded back into the model element information with the built-in function of the modeling software, so that information will be part of the BIM model and the related disciplines will have easier access to this data.

The use of artificial cognitive capabilities in architectural design opens up many new possibilities. The aim of Cognitive Infocommunication is to connect artificial and natural cognitive capabilities and because of digitalization and BIM the whole architectural design process transform. The developed method also shows well that the borders are blurred and with the new method the data interconnection can be even simpler and more efficient [12] [13].

V. Testing the Proposed Solution

This suggested new methodology and the "program" for writing multi-layered structures was tested on three selected projects in a corporate environment. The assigning of multi-layered structure material information was examined to model elements. The time required to load the complete documentation information into model elements was the basis for the comparison. The results are shown in Table II. The tasks mentioned in the table include the following:

A. information content assigned to model elements with manual method: layer models were assigned a layer order code, the task was to assign each material property to a model element;

B. information content assigned to model elements with Excel-based method: layered code was assigned to model, listed and saved in Excel, then material information was assigned using code "vlookup" based on code, values were returned to the software;

C. due to modification information content assigned to model elements with manual method: check the information of model elements with information already uploaded one by one and correct the modified element;

D. due to modification information content assigned to model elements with Excel-based method: layer models and material properties have already been assigned to model models, these values can be saved in Excel and the values can be overwritten and then loaded back into the software using the "vlookup" function.

The above tasks were performed by architects based on the received multi-layered structure documentation. In the same project, the same person did this task, but in each project a different person. Excel-based data loading was performed by BIM managers, also the same person in each project. Architects and BIM experts were both experienced people with years of experience practice.

The method reduced the assignment time by an average of 91% and the re-assignment was also achieved in an average of 87% less time due to some modification. It is important to note that these values are not guarantees for all buildings, as a number of different factors affect time requirements such as designer readiness, client decisions, building characteristics, etc. However, it can be stated that multi-layered structure writing in a structured way is expected to greatly reduce building material modeling and increase accuracy.

TABLE II. Comparison of three buildings: information content assigned to a model element with a manual and Excel-based principle

	Project1	**Project2**	**Project3**
designed function	bookstore	office building	military base
design floor area, cca.	11 000 m^2	25 000 m^2	40 000 m^2
design task status	new	renovation, addition	new
design task complexity	average	complex	simple
A. information content assigned to model elements with manual method	17.5 h	18.0 h	15.0 h
B. information content assigned to model elements with Excel-based method	1.0 h	1.5 h	2.0 h
C. due to modification information content assigned to model elements with manual method	10.0 h	13.0 h	11.5 h
D. due to modification information content assigned to model elements with Excel-based method	1.0 h	1.5 h	2.0 h

VI. Conclusion

Building design consists of many complex tasks, which are now structured into a discipline system. These areas are often organized into separate company or office units, making effective collaboration and communication difficult. The BIM approach, the principle of common model building, provides an answer to this problem. The information content assigned to model elements facilitates efficient information transfer and reduces the possibility of errors. However, this method cannot be applied to disciplines that do not build the model, as there is nothing to insert the 3D data file into. After analyzing this issue from the perspective of a few disciplines, a solution option was formulated.

This approach was applied to the layering tasks of building construction designers. A multi-layered structure writing program was created based on a structured system using Excel software. The name of this method is Dynamic Information Raise. A programmed interface was created using VBA. The multi-layered structure data created with the help of this program were linked to the 3D model, BIM elements, based on unique identifiers. All the necessary information was made part of the common model. The concept was examined, and the developed Excel work environment was tested in three ongoing projects. Based on the results, the time requirement was reduced, in these three cases, by an average of 91% for the first data load, and by an average of 87% for the reload, due to the modification. These values came out for really large projects, it is likely that on a smaller scale there would not be such a reduction in time requirements. Therefore, this procedure is recommendable for large projects. The application of DIR and BIM still has many possibilities (a couple of those mentioned in the article), and many improvements are still needed to make them work well in design practice.

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