Building Information Dashboard as Decision Support during Design Phase

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This paper discusses the Building Information Dashboard, a data representation method which provides a solid basis for decision-makers to make optimal decisions during the design phase of an Architecture, Engineering, and Construction project. We describe an example project workflow where the dashboard is integrated. We sum up the evaluation method, which is the basis of the dashboard, and we research what type of visualization method is best suited to representing this type of data. To this end, an evaluation matrix was created to compare the alternative charts. We take into account what kind of information such a dashboard should represent and what kind of features it should have. We suggest layouts for different use cases - both for professional and non-professional decision-makers, as well as for discipline designers.

Keywords: *BIM, dashboard, decision support, data visualization, data analytics*

INTRODUCTION

One hundred years ago, one architect could possess enough knowledge to design a building that satisfied the demands of the era. At that time, there were only a few major disciplines: building structure, building construction or building statics. Since then, however, every discipline has developed so much, and so many new ones have appeared, that one architect cannot keep up. Depending on the scale of a project in the AEC (Architecture, Engineering and Construction) industry, it can take 10 to 20 designers from different disciplines working on smaller or larger portions of the building. Merely understanding the present demands and requirements of a building requires the involvement of specialists to translate and communicate their field of expertise as it pertains to the building. This means one person - namely, the lead architect - collects an enormous amount of information. This situation is unmanageable without proper tools and proper methods.

From another point of view, we have very good technology to apply, but the way we apply it is not efficient enough. When architects began to use computers during the design workflow at the start of the CAD era, they put their previous design methods into practice in a digital environment. Although it works functionally, the performance is not optimal. As Deutsch R. (2015) discusses, now that AEC projects have become more complex, lack of performance has became a genuine issue for the industry.

What does this mean from a BIM (Building Information Modeling) point of view? We create and manage Building Information Models, which means we make 3-D geometry and then add several types of meta-information to it. As a result, we have a vast database for our building with a great deal of data that we should use. That is why the lead architect has to understand the information, in order to decide which modifications to make to the model. Yet, as previously stated, this information is so complex that we need designers from different disciplines to translate the data into information for the architect. Otherwise, the data is not put to use; and consequently, the data input was a waste of time.

If we want to satisfy the growing performance demands for our buildings, we should act according to Data Driven Design (Deutsch R. 2015). This means we should make more precise models and attach more detailed information to it, so we can perform deeper analyses and more accurate simulations. In most cases, the person or team that makes these simulations and those that designs the building are not the same. Thus, they have to communicate in an efficient way, without loss of information, so the building's performance can improve from version to version.

JUSTIFICATION OF BUILDING INFORMATION DASHBOARD

Plenty of research (Röcka M. et al. 2018, Niu S. et al. 2015) focuses on tools that experiment with various uses of representational 3-D geometry. Nevertheless, in the BIM world, the extra information beside the 3-D geometry is just as important. After researching the literature, we found that, essentially, this information is displayed in two ways during the design phase. One is spreadsheet, which is usually a long list that is hard to read after a certain amount of data. The other is when the data is projected onto the 3-D geometry - for example, when the walls are colored according to their fire categories or their U-values. This type of representation basically works well; however, it is not ideal for every situation, and there are cases when it is unnecessary or disadvantageous - for instance, when disclosing objects, or when we would like to see every object of a certain kind at once, etc.

Our architect students at Budapest University of Technology and Economics conducted research (Porkoláb et al. 2017) by making interviews and online surveys regarding BIM appliance in the Hungarian AEC industry. One conclusion was that, during the design process, it is desirous to have a decision support tool that makes it possible to view all the aggregated data of their actual projects and to take them into account when making decisions.

Building Information Dashboard is a data representation method that lets us perspicaciously compare and display building objects or the whole building from the point of view of various disciplines. It displays the meta-information of the Building Information Model on different diagrams and charts. The decision-makers can see the "big picture" of the building in many discipline dimensions and can tell if the project satisfies all the requirements and regulations. Furthermore, they are able to view the placement of the building on an absolute scale in each dimension.

During the design iteration process, there are several versions of the building. This representation method allows us to compare these along different dimensions. In addition, the building objects can be categorized freely, allowing architects to discover anomalies in the model with regard to performance.

We found building analytics systems which show dashboards or diagrams of information regarding a given building (Gerrish T. et al. 2017), but these are usually FM (Facility Management) or discipline designer oriented (Brambilla A. et al. 2018). They do not allow the decision-makers to follow the full design process. These systems are especially not used in the early design phase of an AEC project, even though that phase has the most impact on the performance of the building during its life cycle.

SUGGESTED DESIGN WORKFLOW USING BUILDING INFORMATION DASHBOARD

Since we are suggesting a decision support method in order to realize data-driven and Integrated Design

(Harding C. 2015), we would like to show one example of a project structure where it is integrated. There may be other functioning variations as well, which could be part of our future work; yet, the aim of this article is to introduce Building Information Dashboard itself.

In the following section, we will discuss the design workflow (Figure 1.) where a contractor trusts a general architect designer studio with the design of an approximately 5000 m2 office building. In the studio, the lead architect is responsible for the project, and he is the one making global decisions concerning the design of the building. Other architects creating the building are considered one of the discipline designers, such as, among others, HVAC engineers, civil engineers, fire engineers, etc. The BIM server is a computer where the main database of the building is stored. It can communicate with the project participants via IFC file and via web technologies. It runs several programs which are used by the studio (e.g., project management tool, CAAD server, etc.). Still, the most important one, from our point of view, is a dashboard service which represents the building's data.

The design process starts with the contractor briefing the lead architect about the project demands and opportunities. Then the lead architect summarizes and forwards the demands and opportunities to the discipline designers. The discipline designers submit design intentions and suggestions to the architects based on the project attributes for the first version of the building.

We have defined five actions that the discipline designers may take: make a 3-D model, add indicator metrics to an already existing model, make an evaluation of an existing model, make a comment, and place a warning marker.

The architect team makes and sends the first version of the 3-D model with the attached meta-information to the discipline designers. Discipline designers, according to the given milestone, assess requirements and give present performance values to items based on their field of expertise. Additionally, they can place warning markers or contribute comments as well.

All this work can be followed and checked by the lead architect, or even the contractor, at the BIM server via the Building Information Dashboard, where they see the project overview, the warnings, and the comments. They may even zoom in one part of the overview and investigate any anomalies or errors in the building data. Afterwards, design iteration begins, when these steps are repeated with increasing detail each round. Throughout the entire workflow, the dashboard shows the actual performance of the building, so the lead architect is capable of making globally optimal decisions based on data displayed on the dashboard.

METRIC OF EVALUATION

We submitted an article to Periodica Polytechnica Civil Engineering in May 2018, in which we provide a more detailed handling of this topic. In the following, we will simply provide the essence, so the context concerning the dashboard is understandable.

The metric of evaluation is a core question of the dashboard. When starting a project, the scope has to be decided - namely, what discipline designers are going to take part in the project and which elements of the building are they going to evaluate.

During the evaluation process, both a present performance value and a requirement value are added to each object by the designers. For example, the building's energy engineer adds 1.8 W/m^2K as a present U-value and 1.6 W/m^2K as the U-value requirement for Door-01. If we would like to check whether objects, such as this specific door, are satisfying their requirements, we perform conflict detection. As a result, warning markers are placed where conflicts are detected. If we would like to run conflict detection on a group of objects or on the whole building, we have to aggregate data.

During the aggregation process, when we would like to compare or sum up the data of objects which may have different indicator metrics, we need to make a conversion on the physical measurement

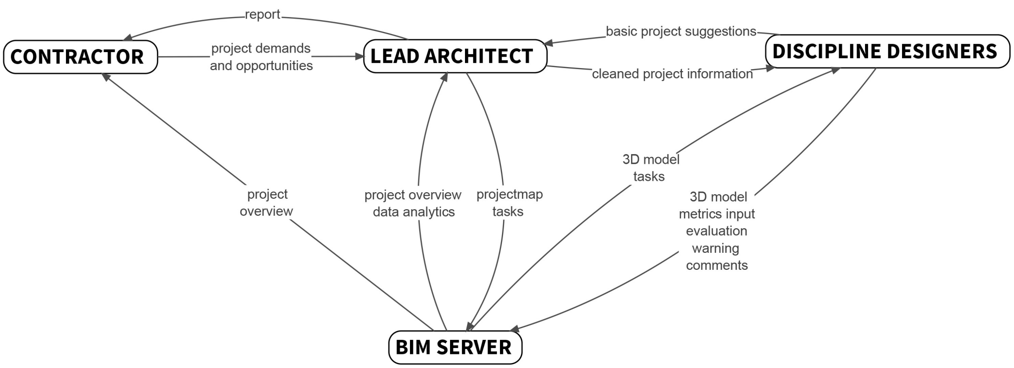


Figure 1
The workflow of a project using Building Information Model Evaluation Method

units to another scale. We chose a zero-to-ten scale (Figure 2.) where zero represents the worst and ten represents the best solution. All the discipline designers determine their own scale based on their own experience and professional opinion - i.e., what is zero and what is ten in their own field. For example, if the designer would like to evaluate the thermal performance of a given door, then he checks the U-value of that exact door and may research the market to determine the best and worst U-values for doors. According to the research, he can decide what U-value belongs to 0 and what U-value belongs to 10, thus enabling him to map the exact U-value of the door to a scale number.

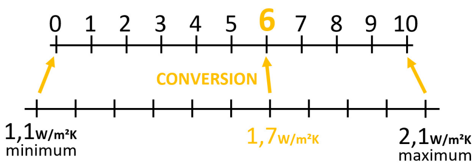


Figure 2
Value conversion from a physical measurement unit to a zero-to-ten scale.

DATA SOURCE FOR BUILDING INFORMATION DASHBOARD

The dashboard uses a BIM data set incorporated into CAAD software by the architectural team. It contains the structured three-dimensional model and the attached meta-information. The structured character is important, because the dashboard displays data in an object-oriented way, arranged in a hierarchy. Since we believe in open-source concepts and that every project participant should have their own free software choice, our focus is on the OPEN BIM environment. In this case, the main data exchange format is IFC. We found that using the IFC description tag to store the discipline-related code is a simple way to solve the task, because we were able to read out the input values and visualize it with Python script. At the same time, this tag gave us freedom in terms of the quality and restrictions of input data.

VISUAL APPEARANCE OF BUILDING DATA

There are three main tasks for the dashboard to solve from a visual point of view. The first is to visualize the building's aggregated evaluation data from all discipline aspects. Thus, decision-makers can tell if each aspect is at a satisfying level or not. The second task is quite similar, only now the visualization should only focus on individual object evaluation. The third task is to show different groups of objects in a comparable manner along different disciplines.

The Building Information Dashboard should allow the project participants to use it in two ways - in a narrative and in an explorative way. Narrative is when the dashboard explains to us what the problem is and where can we find it. For example, we look at the charts of the whole building, and we see if the different values are all right. If not, it shows us a warning marker; so we know where the problem is, and we can track it back to its source. This only works with the most common problems that we are prepared for in advance - for instance, when there is a conflict between an object value and its requirement value.

On the other hand, explorative is when we take a look at the Building Information from several different points of views, trying to discover anomalies which are not trivial. For example, the whole model may be conflict-free, but if we arrange the objects along different logical lines, it can turn out that, although we satisfy all the regulations, the objects with the weakest performance metrics are concentrated in one area of the building, which may have unexpected effects.

Chart for Visualizing Evaluation Values

In their research, Jusselme et al. (2017) aimed at identifying suitable visualization techniques that increase the usability and the knowledge extracted from the building simulation data set. They created an evaluation matrix to decide which type of diagram best suits their purpose. We chose the same technique to find the best diagram types for these discipline evaluation data.

We researched the possible diagram types at the webpage of datavizproject [1], which is a comprehensive archive of data visualisations. We chose four diagrams to compare in the evaluation matrix: heatmap, butterfly chart, dot-plot, and grouped bar diagrams. (Figure 3.) These charts should show the present performance value and the requirement value of an object at the same time. They need to allow the viewer to compare these values along at least two disciplines. It should be easy to understand, while it needs to display plenty of extra information: titles, other statistical data and markers. It needs to be scalable, so it remains intact whether there are few or numerous values. Thus, we created five evaluation aspects: comparability, title placement, maximum number of dimensions, ergonomy, and ability to represent extra statistical data. Then we graded these four alternatives on a zero-to-two scale, where zero is not good, one is good, and two is excellent. It turned out that the butterfly chart best suits our purpose, and grouped bar is slightly behind. Both may have their use cases: butterfly chart is better in comparing two dimensions deeply and grouped bar is better to show an overview of the evaluation.

	Heatmap	Butterly chart	Dot-plot	Grouped bar
comparability	0	2	1	2
title placement	1	2	0	1
maximum dimensions	2	0	1	2
extra statistical data	1	1	2	0
ergonomy	1	2	2	1
sum	5	7	5	6

Figure 3
Evaluation matrix for deciding which chart best suits representing evaluation values

Figure 4. is an example of a butterfly chart showing discipline values of object groups. Conflicts between present performance and requirement values are easy to locate, while each object value is comparable to the others or to the average. The numbers at the start and at the end of the bars are easy to read and related to the corresponding object. These numbers can be either integers or floating point numbers. The former is a value originally meant for the zero-to-ten scale, while the latter indicates a converted value, derived from a physical unit of measurement.

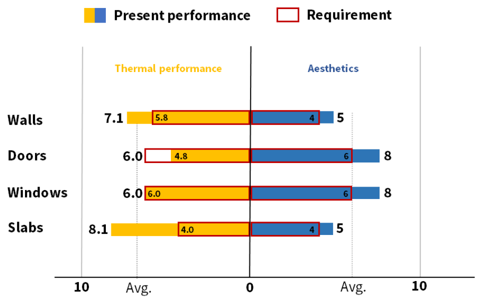


Figure 4
The butterfly chart representing the thermal performance and aesthetic values for object-groups.

Structure of the Dashboard

The main goal of Building Information Dashboard is to make building data accessible in a complete, efficient, and user-friendly way. This main goal has three parts. The first is to let the user explore the database in a manner that a human eye can process. The second is to alert users to errors and conflicts. The third is to allow project participants to communicate with each other in an object-oriented way. This means that comments which the project participants make belongs to objects or object groups. This way, reasons behind certain design decisions can be added to the database, which allows for the realization of Transparent Design (Kovacs A. 2017).

We have collected features that we think are important, regarding what the dashboard should have in order to accomplish the above-stated goals.

Feature one is a chart representing the object evaluation values and satisfying the demands discussed previously. Feature two is a 3-D view. As stated in the Justification of Building Information Dashboard Section, so far the main method for exploring the BIM model was via 3-D view, which is not ideal for every situation. We have also discussed the opposite option, which is only using diagrams and charts to explore the model. According to our research, the most efficient way is to use these two techniques side by side. The 3-D view compliments the information view nicely, because the object selection is user-friendly, and it is easier to understand objects in context. Feature three is an object filtering function with a zoomable object structure. This means that users can set criteria concerning the objects shown on the chart - for example, to show only the walls thicker than 30 centimeters. The zoomable object structure enables users to navigate in the object hierarchy - for instance, to determine the reason for the warning marker on the walls at the object-group level. (Figure 5.)

Feature four is the warning markers. If there is a conflict in the values, warning markers should appear automatically. During the aggregation process, the warning markers are aggregated as well. Thus, for example, if Wall-04 has a conflict, all of the levels above will have a warning marker. (Figure 5.) Feature five is the object-oriented discipline design comments, which were discussed earlier. Feature six is a simultaneous 2-D / 3-D object selection. This means that what users select in the 3-D view is selected and displayed simultaneously on the chart as well, and vice versa.

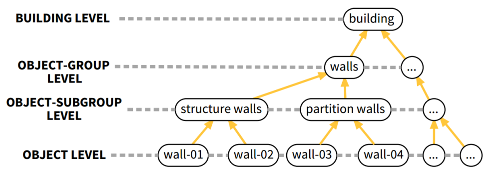


Figure 5
An example for the hierarchy of objects in the BIM model, where the reason for the warning marker can be traced

Different Use Cases of the Dashboard

In the following section, we give suggestions for dashboard layouts for different use cases. There are three types of users that the dashboard has to satisfy.

The first is the decision-maker, who is not a professional, but who would like to see the overview and the actual status of the project. (Figure 6.)

The second is the decision-maker, who is a professional - for example, the lead architect who is responsible for the design of the building. He would like to see the overview and the details, and he wishes to explore the model for anomalies. (Figure 7.)

The third is the discipline designers, who actually create the model, add meta-information to it, and make the evaluations. (Figure 8.)

CONCLUSION

In this article, we took into account the challenges of decision-makers in today's AEC projects. We explained a data representation method that helps all of the AEC project participants, including decision-makers, to create buildings that which perform better. Furthermore, the method helps manage these projects in a more efficient way. We also showed how this method contributes to realizing Integrated Design.

Figure 6
Dashboard layout for non-professional decision-makers

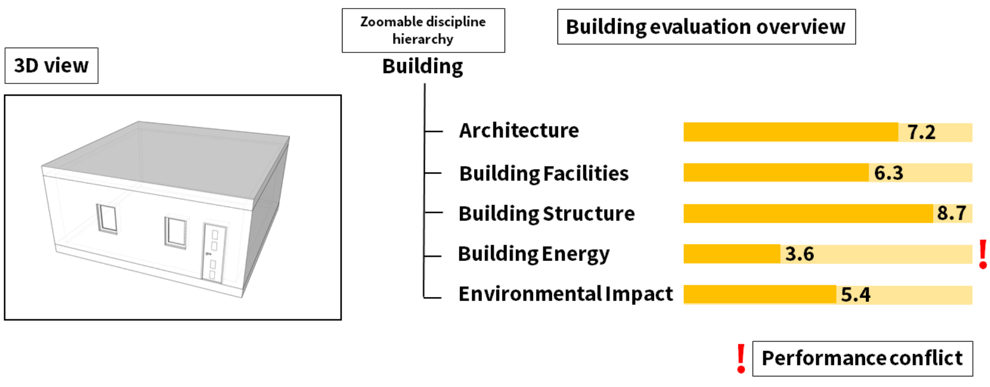
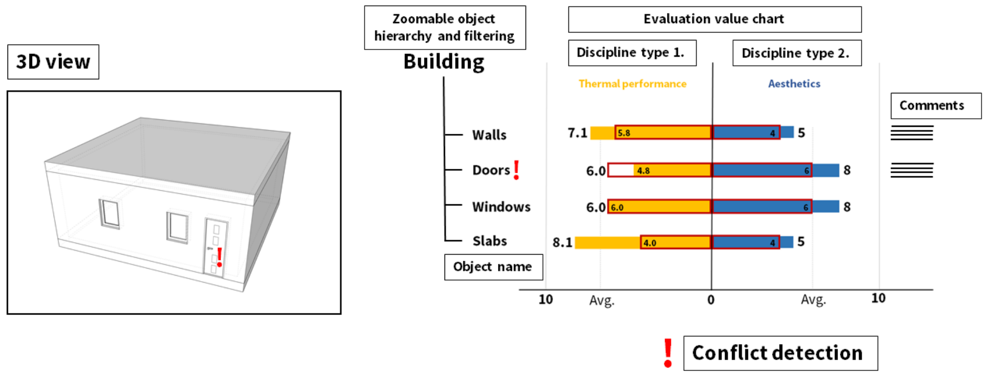


Figure 7
Dashboard layout for professional decision-makers



The operation, the structure, and the layout of the dashboard were discussed. We tested each part of the technology behind the dashboard without encountering any remarkable obstacles. Finally, we analyzed several charts to come up with one that suits all the aspects of evaluation data visualization that we wished to satisfy.

Implementation of the dashboard presented here is still in progress. During the ongoing development process, we consult with designers and collect feedback on a regular basis. Evidently, the method of data input is crucial, because this method places more administrative workload on discipline designers. Thus, it is always a key issue to communicate the scope of the evaluation clearly. On the other hand, it has yet to be determined how much of this extra work can be automated by algorithms.

We feel that changing the design workflow from its traditional application to the use of this dashboard will require plenty of effort and self-discipline at the

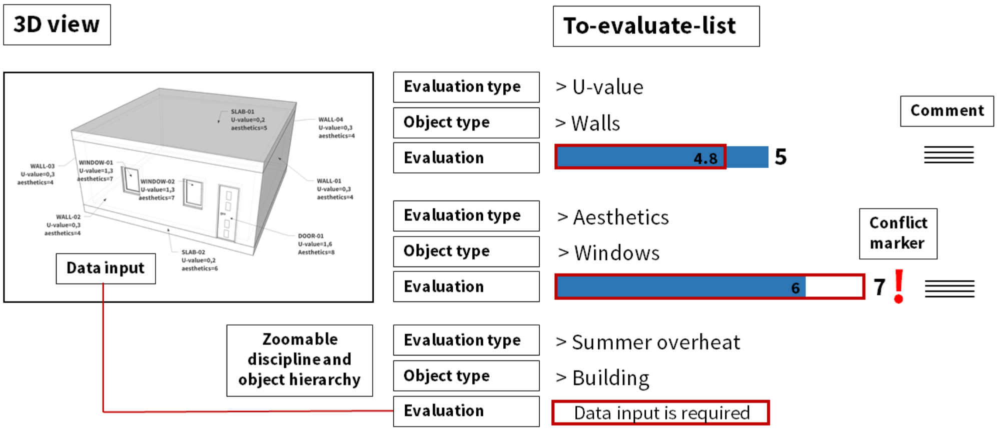


Figure 8
Dashboard layout for discipline designers

initial stages. Nevertheless, we firmly believe that it is worth it in the long run. We have yet to prove this in our future research. We would like to measure the productivity growth of our method. After a design studio finishes a project with the dashboard, we can compare the amount of time and effort they invested in this project to another project that they accomplished beforehand, without this method. This will give us a sense of the improvement in productivity. Over time, Building Information Dashboard can be implemented as a decision-support tool in other CAAD or project management software.

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