BUILDING INFORMATION MODELING TOOLS: OPPORTUNITIES FOR EARLY STAGES OF ARCHITECTURAL DESIGN

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ABSTRACT

In the practice of building design, numerous researchers point out that, at the early stages of architectural design, many significant decisions are taken to directly affect functional qualities, the performance of the building, aesthetics, and the relationship of the building with the natural environment and climate, even if there is no certain and valid information to create and obtain satisfying design.

In this paper, I particularly focus on the early stages of architectural design and search for the opportunities provided by Building Information Modeling (BIM) tools, towards the concept of performance analysis and aesthetic variations. Study also includes case study implementations which visualize the early processes of architectural design with benefits of BIM under different conditions to evaluate its opportunities during these design processes. To clarify and to test the benefits of BIM tools, the task is done to create a concept model with Vasari and Revit software. Participants are asked for designing alternatives within the given requirements and synchronically, I analyzed the process within the perspective of how design products are shaped and also how the process effects the designers while they are designing.

Later on, I observe how participants use the tool to obtain aesthetic variations and how tool provides a connection between aesthetic issues and the performance realities. At this stage, BIM tools provide an evaluation platform to crosscheck the current design alternatives with the selected building components and environmental conditions such as temperature, sun light directions, wind directions, and so on. By this way, designers are able to realize the relationship between the design product and the environment and also be able to obtain performance analysis of the alternatives on the very early stages of architectural design.

As a result of these case studies, I observe that the BIM tools (Vasari and Revit) which are used in this study, do not provide an automated design process, but only analyze the designer's existing design to enable the evaluation of the relationship between the building and the environment. Then, the design relies on both the functional realities and the subjective judgements of designer. This operation continues as an iterative process until designer feels satisfied for his/her design product.

As a summary, early stages of the architectural design are accepted as the weakest point of the BIM systems. In this study, two case studies have been implemented to reveal how BIM can help to designers in these stages. As a result of the

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implementations, it is understood that BIM is a powerful early stages of architectural design tool, not for designing but for design supporting.

Key words: conceptual design analysis, computational design analysis, building information modeling

1. INTRODUCTION

Architecture is a profession that is in a tension between imagination and reality. The architect's task is to convert the client's dreams into a concept design which is expected to lead to a functional, legally proper, and aesthetic design (Foqué, 2010). The role of the architects in the related process often begins from the starting point of the project to the end of the construction. As the architectural design process has a complicated structure with different purposes, it is divided into stages.

Numerous researchers point out that, at the early stages of architectural design, many significant decisions are taken to directly affect functional qualities, the performance of the building, aesthetics, and the relationship of the building with the natural environment and climate, even if there is no certain and valid information to create and obtain adequate design.

In this paper, I particularly focus on the early stages of architectural design and search for the opportunities provided by Building Information Modeling (BIM) tools, towards the concept of performance analysis and aesthetic variations. The focus of the study is to offer, not an alternative way for traditional design practices but a supporter. From this perspective, firstly, I review the literature on early stages of architectural design, its characteristics, usual habits, and positive / negative aspects. The following two sections (Case Study A and B) are the implementations of BIM tools (i.e. Vasari and Revit) in the early stages of architectural design. These sections also include assessment of the cases to discuss the strong and weak features of the tools. In the last section, I also evaluate the findings of the case and literature review in the same context to constitute a new approach for early stages of architectural design.

2. EARLY STAGES OF ARCHITECTURAL DESIGN

Stages of architectural design process are defined within the various procedures by different authorities. For instance, the Royal Institute of British Architects' (RIBA's) Plan of Work includes nine main stages as inception, feasibility, outline proposals, scheme design, detail design, production information, bills of quantities, tender action, and project planning (Thompson, 1999). From the perspective of RIBA, the early design stages refer to inception, feasibility, outline proposals, and scheme design.

Other studies show that, in the early stages of architectural design, sketching and drawing with paper and pencil still has an important role for exploring possible design alternatives, evaluating the ideas, and also communication with self (Do, 2002; Lawson, 1994; Herbert, 1993; Graves, 1977; Schön, 1985; Goldschmidt, 1989). On the other hand, being digital makes CAD softwares more effective than traditional drafting methods in terms of time, cost and ease of use. However, these CAD software which are really useful for drafting, are not suitable for initial design tasks like exploring new ideas.

In this stage, designers also are expected to decide on key factors such as building orientation, building shape, structural system, building envelope and interior finishes with inadequate and indefinite information (Gervasio et. al., 2014; Granadeiro et. al., 2013; Oral & Yılmaz, 2002; Oral & Yılmaz, 2003; Hong, Chou & Bong, 2000; Holm, 1993; Gratia & De Herde, 2003). These decisions which are taken with often inadequate information on the site, climate, geography, also provide a basis for the final performance and the aesthetics of the final outcome.

To address both the negative impacts of designing with inadequate information, and the emergence of the performance requirements for the building efficiency, researchers and practitioners become aware of the need for digital preliminary design information databases which are systems including all relevant statistical informations about the existing environment such as temperature, sun light directions, wind directions and so on.

Do (2002) mentions that in order to support creative design, design tools might offer additional capabilities to standard drafting and editing software. She argues about a computational sketching system and emphasizes in parallel the importance of knowledge-based editing, simulation, and accessibility of relevant design information. Since 2002, these database systems have been more and more used as integrated parts of BIM software. Now, designers can exploit the advantages of BIM software (such as powerful drafting, visual analysis reports, scheduling and budgeting features) and also analyze their designs within the conditions of given information in the same media.

Foqué (2010) expresses that "intuitive thinking and rational thinking are not opponents; they are the twin poles between which the artist structures reality". In addition, he also asserts that with the emergence of modernity, architecture practitioners hover between science and art (Foqué, 2011). Within this context, he states that research by design is a keystone as it comprehends possible realities, searches their attraction, shifts the existing reality by implementing a new one and evaluates the resultant reality by creating design applications, relying on technological knowledge and artistic interpretation (Foqué, 2011).

All in all, I can underline that taking advantage of essential information in the early stages of architectural design is useful and important for the whole design process and the final product. Additionally, BIM tools with their "information" capability, operate as an improved architecture software with powerful 2D and 3D drafting features, performance simulations, and visual analysis feedbacks. It must be mentioned that these tools (Vasari and Revit) do not provide an automated design process, but only analyze the designer's existing design to enable the evaluation of the relationship between the building and the environment. Then, the design relies on both the functional realities and the subjective judgments of designer.

In this section of the paper, I study the current realities of the early stages of architectural design by literature review, and then, I explain how BIM tools can offer new opportunities within the design processes. Below are the implementations of two case studies to evaluate the efficiency of BIM tools within the context of basic design decisions with regards to the later stages of architectural design.

3. CASE STUDY A

3.1. Problem Definition

Case Study A is an implementation of designing an office building in Istanbul/Turkey, at the very early stage of architectural design, which is needed to have 5000 m2 area with decent energy performance. I determine some constraints to make design simpler and also to give Vasari (conceptual mass design tool which is used for this implementation) more freedom. These constraints are: Assuming the immediate environment is unconstructed (1), evaluating the aesthetic issues as only aesthetic variations (2), assuming land use property limitations such as ground usage or maximum height as free (3), and also ignoring the relationship quality between the topography and the building model (4). There is also another constraint that the only design tool used in this case is Vasari.

3.2. Case Study Methodology

At this case, to clarify and to test the benefits of BIM tools in the very early stage of architectural design, the task is done to create a concept model with Vasari software and to observe its reflections on the designer and design product. Case study has been done by a master degree student of architectural design computing department who has a moderate BIM knowledge.

Participant is asked for designing alternatives within the given requirements. Synchronically, I analyzed the process within the perspective of how design products are shaped and also how the process effects the designer while he is designing. Later on, I observe how participant uses the tool to obtain more aesthetic product and how tool provides a connection between aesthetic issues and the performance realities.

3.3. Implementation

Towards to the benefit from the capabilities of Vasari, case study participant decided to create three basic alternatives to work with. These alternatives were the basic masses which are dimensioned as 25x100m with two floors, 20x50m with five floors, and 22.3x22.3m with ten floors. At this point, he also decided to differentiate the alternatives within themselves. To achieve these variations, participant used the conceptual mass analysis and the energy model feature. Within energy model feature's settings, participant defined the building type as office, location as Istanbul/Turkey, building operation period as 24/5 facility, and HVAC system as Central VAV, HW Heat, Chiller 5 (Figure 1). Also, participant used the default building component settings of Vasari and automated three more alternatives (percentage of glazing as 20%, 50%, and 80%) for each initial three alternatives. All the information that the software used when producing the new alternatives are taken from the database of Vasari.

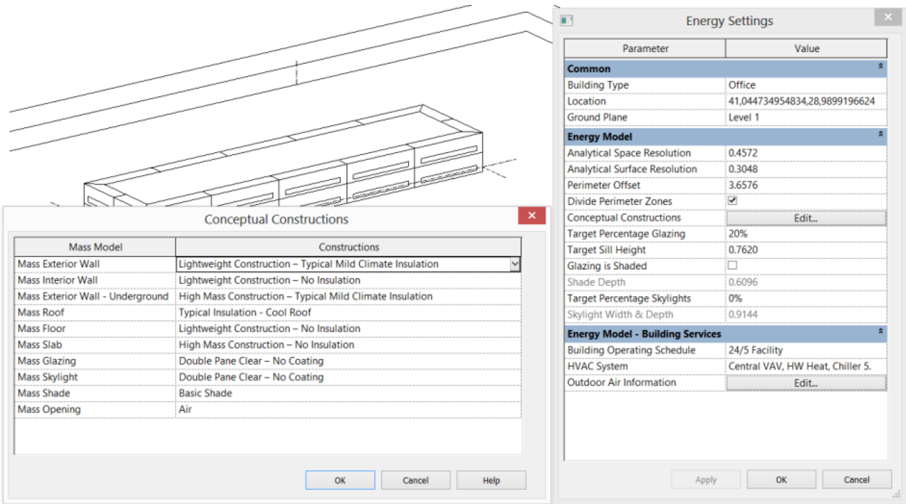

Figure 1. Energy Settings of one of the alternatives

At the end of this semi-automated process, participant obtained nine different office building variations with all different energy performance and appearance (Figure 2). Later on, participant compared the performance analysis of the alternatives and noticed that the one (Alternative 3 with 80% Glazing, ninth alternative) which participant was willing to continue his designing process, was also the one with the worst performance. To make better of the performance of the building, participant decided to change some components of the building such as high insulation construction materials and one meter length sun shading units (Figure 3). With these building components, ninth alternative achieved the requested requirements and was approved.

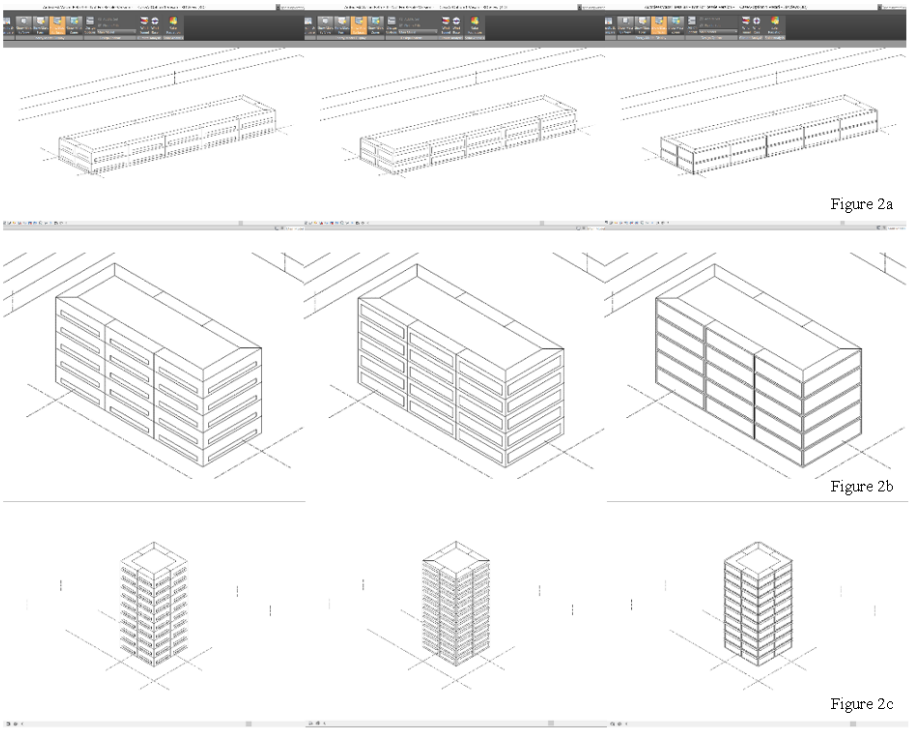

Figure 2. Three conceptual mass alternatives with their three derivative alternatives

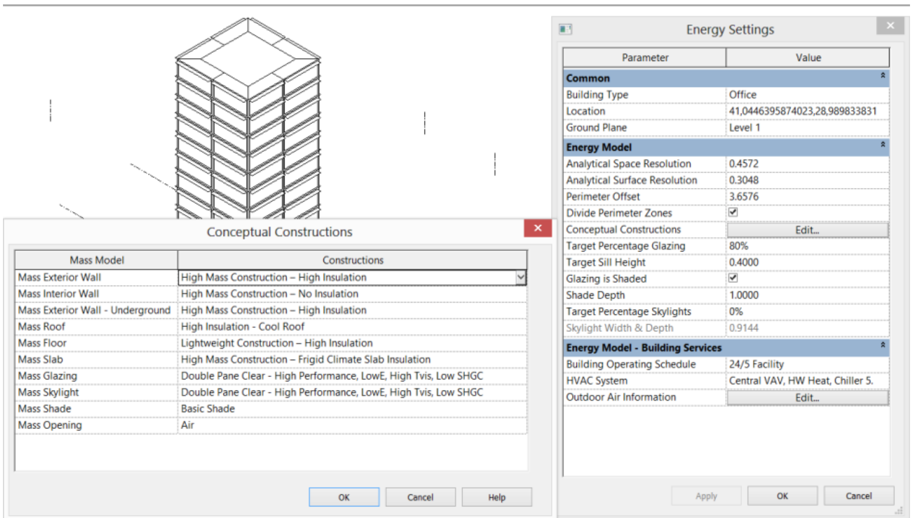

Figure 3. Ninth alternative with the high insulation building components and sun shaders

After the alternative was approved as an initial design product, participant applied solar radiation, wind (Figure 4), and shadow analysis to the model to obtain the related information about the relationship between the environment and the building. Again, participant did not have to know about the statistical information about the environment because Vasari includes them in its own database. As a result of this information, participant collected the information about which direction wind and sun lights come from, and how they interact with the building.

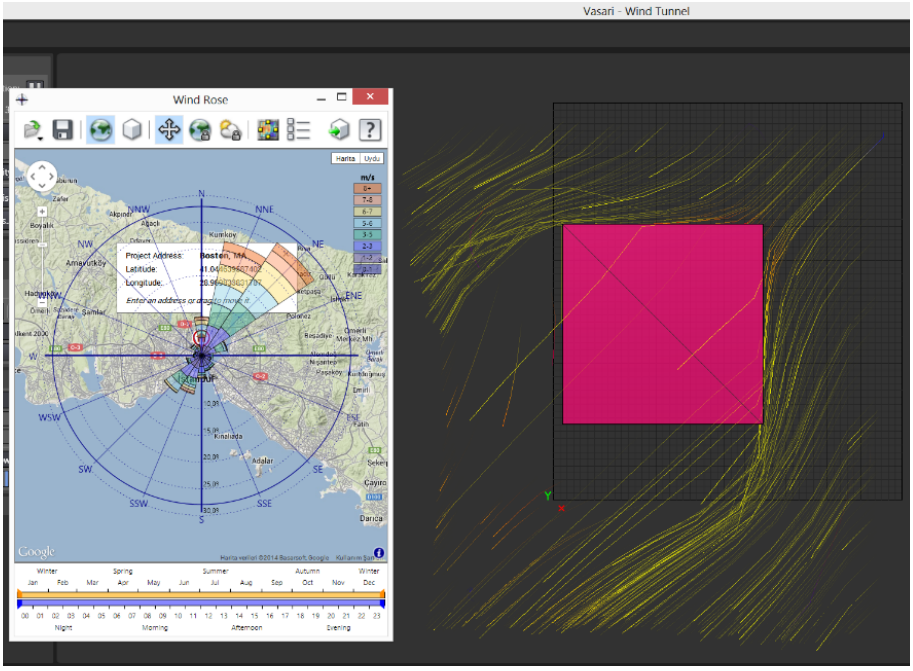

Figure 4. Wind analysis simulation representation of the given date

3.4. Findings

While observing the Case Study A, I notice that the participant uses the feedbacks of the Vasari to provide a better design. As it is mentioned above in the introduction section, Vasari provides a great opportunity to support design ideas with analyzing them from the perspective of performance. In addition, whenever a designer decides to change a variable, Vasari also provides an instant visual response which lets a designer to see both the appearance of the model and the new performance values.

With the capability of the database system and the various analysis features, Vasari offers a new way of evaluating design products which is not easy to do without digital computing tools. Thus it is clear that this situation will make Vasari an important design tool in the early stages of architectural design.

4. CASE STUDY B

4.1. Problem Definition

Case Study B involves the process after the Case Study A. In this implementation, conceptual mass design of the approved alternative was exported to Revit and modelled with the building components such as exterior walls, windows, and interior walls. There is still no detailed information about the specs of the building components but Revit recognizes these components as what they are. This implementation contains the process which starts from the end of the conceptual mass design to the stages of documentation.

4.2. Case Study Methodology

At this case, to clarify and to test the benefits of BIM tools in the scheme design stage of architectural design, the task is done to create a virtual building model with Revit and to observe its reflections on the designer and design product. Case study has been done by the same participant and criteria have been evaluated as the same with the Case Study A.

4.3. Implementation

To achieve from what it is expected from Revit and Case Study B, he started the process with creating a virtual building information model which has the main components such as walls and windows without any technical specifications. These components also have the feature to add related information in later stages when some detailed decisions are taken into consideration.

After completing the virtual model, participant obtained six different spaces from the interior walls and defined them as rooms. After this process, participant also had a chance to analyze each room and to decide specific decisions about room's area, volume, performance loads and qualities (see Table 1). Later on, participant decided to change some parameters of the spaces to obtain all the rooms would have minimum requirements. To improve these kinds of space specific analysis and decisions, Revit also has more detailed and differentiated analysis tools as add-ons, but they are ignored within this study.

At the end of the implementation, with all decisions taken, participant applied solar study simulation which demonstrated sun activity from the date of 22 April 2014 to 22 April 2015. In this case, because of ignoring the constructed environment, simulation only provided to achieve the opportunity of seeing the relationship between direct sun light and the building. But also participant noticed that it would be really useful when designing in a constructed environment since it directly affects the accessibility of sun light and also wind load.

4.4. Findings

Revit as a BIM software is able to do both conceptual mass analysis and building elements mode analysis. In Case Study B, the conceptual mass analysis process which is already done within the Case Study A with Vasari is ignored. I notice that if a designer uses the Vasari as an early stage design tool, Revit has not much more thing to give if not using extensive add-ons. On the other hand, Revit constitutes a working and communication media which link the works done within the very early stages of architectural design to the maintenance or even demolition stages.

Space Summary - 1 Space

Inputs	
Area (m²)	86.92
Volume (m³)	211.95
Wall Area (m²)	48.89
Roof Area (m²)	0.00
Door Area (m²)	1.95
Partition Area (m²)	0.00
Window Area (m²)	27.19
Skylight Area (m²)	0.00
Lighting Load (W)	936
Power Load (W)	1,216
Number of People	4
Sensible Heat Gain / Person (W)	73
Latent Heat Gain / Person (W)	59
Infiltration Airflow (L/s)	9.4
Space Type	Office (inherited from building type)
Calculated Results	
Peak Cooling Load (W)	**4,056**
Peak Cooling Month and Hour	August 09:00
Peak Cooling Sensible Load (W)	3,817
Peak Cooling Latent Load (W)	239
Peak Cooling Airflow (L/s)	257.9
Peak Heating Load (W)	**2,285**
Peak Heating Airflow (L/s)	120.6

Components	Cooling		Heating	
	Loads (W)	Percentage of Total	Loads (W)	Percentage of Total
Wall	165	4.07%	369	16.17%
Window	1,666	41.07%	1,668	73.00%
Door	0	0.00%	0	0.00%
Roof	0	0.00%	0	0.00%
Skylight	0	0.00%	0	0.00%
Partition	0	0.00%	0	0.00%
Infiltration	154	3.81%	247	10.83%
Lighting	752	18.54%		
Power	978	24.11%		
People	341	8.40%		
Plenum	0	0.00%		
Total	**4,056**	**100%**	**2,285**	**100%**

Table 1. Room Specific Report for the Space named as "1 Space"

5. CONCLUSION

The main objective of the study is to reveal the opportunities of the BIM tools for the early stages of architectural design. To examine the features which BIM provides for the designers, two case studies have been implemented. During these implementations, I notice that Vasari and Revit don't offer powerful features for designing in these stages, but they offer significant and useful capabilities to judge the design product and also indicate the potential advantages which can be easily applied to the existing product without any certain and detailed information.

For instance, during Case Study A, the designer created nine different alternatives with given requirements for obtaining office building mass designs. When this basic design process was completed, he was also able to obtain the detailed analysis reports for all these alternatives. Later on, he noticed that the one which he felt close to continue, was also the one with the worst performance. By this way, Vasari warned the participant about the performance outputs of his design and also advised him to change the related predefined construction materials to obtain better results. On the other hand, during Case Study B, the designer was able to work with more definite factors such as the area, volume, wall area, and window area of the room. Also, there was some estimation about the lighting, power, cooling and heating loads. With these analysis, he decided to change the interior wall settlements to provide larger areas for the needed rooms.

In this study, two major acceptances were taken as case study constraints. Firstly, the nine alternatives were accepted enough for the aesthetic form seeking. Because the task is not designing an aesthetic product but it provides to understand how these tools interact with designers during the evaluation of design products. Secondly, neighborhood relationships such as nearby buildings, land use issues, social impacts, and topography are ignored. For this reason, it is needed to do more case studies with more complex functional and performance requirements within the respect of aesthetic performance to reveal more benefits and/or limitations of BIM tools during the early stages of architectural design.

As it can be understood from the previous examples, BIM tools provide an opportunity to test the existing design products and also offer a way to improve them. Then, the designer also has a chance to design and analyze their own ideas within an iterative process until they feel satisfied. This way of working proposes a connection between functional realities and designers' subjective judgments which can interact with themselves.

In conclusion, BIM is still an ever-developing system which is one of the most popular research and implementation topics of AEC industry. From the first stage of the design to the end of the building life, BIM offers many benefits to its users. In spite of that, early stages of the architectural design are accepted as the weakest point of the BIM systems. In this study, two case studies have been implemented to reveal how BIM can help to designers in these stages. As a result of the implementations, it is understood that BIM is a powerful early stages of architectural design tool, not for designing but for design supporting, which visualizes the given inputs of climate, geography, material information and so on, to analyze and improve current solutions.

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