Expected Architects Acceptance of a BIM Tool to Optimize the Building Energetic Performance

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Abstract. This paper presents an evaluation of the architect's acceptance of new proposal toll, that will be integrated in a BIM environment, to be used to optimize in the space organization in function of the energetic performance of a building, in comparison to the traditional solutions alternatives. This evaluation used the social psychology to evaluate the architects expected acceptance of this tool. One hundred two architects participated in this study, the main results showed that only 61.8% of the sample agree that this BIN solution can help their performance in project. This result can be justified by the values of effort expectation that 79,8 % believe that they need to have a high effort to be able to use this application. The need to a good usability and user experience to improve the interaction with this application, is a very important aspect to change those results and to improve the use of BIM solution in their work tasks.

Keywords: User Acceptance · BIM tool · Energetic Performance · Architects

1 Introduction

This paper outlines part of a research project, Ren4EEnIEQ, funded under the Portuguese Foundation for Science and Technology (FCT) and European Regional Development Fund (FEDER), which involves the assessment of acceptability and intention to use a new tool for architects. The project objective aims to develop a comprehensive tool for deep building renovation, which comprises the building survey, design generation, building geometry optimization, and energy system and constructive system optimization in single BIM add-on tool for architects. The goal is to help the architect looking for the best building renovation solution that minimizes energy consumption and maximizes indoor environmental quality in a cost-effective manner.

The evaluation of the user acceptance was done according to the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2): performance expectancy; effort expectancy; social influence; facilitating conditions; hedonic motivation; and behavioral intention to use the BIM tool.

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Unified Theory of Acceptance and Use of Technology (UTAUT)
UTAUT is used in technology acceptance studies to predict system use and to make decisions about technology adoption and use. The model incorporates eight other models that foresee the adoption, acceptance and use of technology, bringing coherence to the technology acceptance literature and providing a unified view of technology [1, 2].
The first UTAUT presented by Venkatesh, Morris, Davis, & Davis [3] has four constructs that influence behavioral intention to use a technology (performance expectancy, effort expectancy, social influence, and facilitating conditions). These authors have defined performance expectancy as the degree to which the user believes that using the tech will help him achieve performance gains; effort expectancy explains the degree of ease associated with the use of technology; social influence indicates the degree to which the user perceived that others (e.g., friends, colleagues and family) believe he should use the technology; and facilitating conditions define the degree to which the user perceives the existence of an infrastructure that supports the use of technology.
Later, Venkatesh, Thong and Xu [4] adapt UTAUT and introduce UTAUT2, including three more constructs (hedonic motivation, price value, and habit) and new connections between all variables and the behavioral intention to use. They also include individual variables: gender; age; and experience. Ignoring the voluntariness, present in original UTAUT.
Reviewing other studies, we understand that it is possible to involve other variables within this theory, example is the case of Shuhaiber & Mashal [5], investigated how then involved the personal characteristics of users (trust, awareness and pleasure / fun) with the intention of using a system. Chintalapati, Srinivas, & Daruri [6] puts the Perceived usefulness sub-variable of Performance expectancy, the Perceived Ease of Use sub-variable of Effort expectancy and User Attitude as variables responsible for intent to use (Behavioral Intention). Manis & Choi [7] study intention to use through Perceived Usefulness, Perceived Ease of Use, Perceived Enjoyment and Attitude toward using. Recently Yang & Wang [8] present a more simplified study model where they test the direct relationship between Perceived Usefulness and Perceived Ease of Use with Intention to Use. This flexibility of adding and removing variables shows us that it's possible to select the most appropriate constructs for each case study.

1.1 Objectives

This study focused on expected user acceptance of a BIM add-on tool for architects. In this context, the main objective is to evaluate the acceptance of a concept showing an interface and explain what they can do with it.

2 Methodology

The online survey was conducted to capture the users' expectations regarding the use of such systems. The questions were designed to get subjective evaluations of the following parameters of UTAUT2: performance expectancy, effort expectancy, social influence, facilitating conditions hedonic motivation, and behavioral intention to use. A video has been created with a scenario that enables the comprehension of a potential use of the program before answering the questions.

2.1 Survey Structure

The survey by questionnaire, consisted in three parts: (1) the informed consent, (2) the video about the tool, (3) the questions related to the tool and personal variables.

About part 3, the questions were inspired by Venkatesh et. al [4] research and adapted to assess the acceptance of Portuguese and Brazilian architects and architecture students. They were invited to participate by email or contact via social network LinkedIn.

Adapting the questions according to the study theme, we selected eighteen items to evaluate the parameters present in the UTAUT2. All these items were measured using a seven-point Likert-scale from 1 (completely disagree) to 7 (completely agree). Three questions were collected regarding each construct except price value and habit. The price value and the habit are not suitable constructs for study, because the tool will not bring a direct cost to an employee in his studio, for example. It cannot become a habit when it doesn't exist.

With the performance expectancy we want to know if the architect believes that the tool is useful for his daily life, he would perform well, and would help him get his work done quickly. At effort expectancy let's evaluate if the user feels able to use the program without difficulty and could become skillful. The variable social influence will indicate whether colleagues and the organization can influence program use. The facilitating conditions are related to the support, he has the necessary knowledge, if he knows how to use it and if he could overcome his difficulties. With the hedonic motivation we analyze if using the tool can be enjoyable or fun. Lastly, behavioral Intention, we ask directly if the user has the intention to use the tool in the future.

2.2 Video Scenario

To engage the participants in the fill of the questionnaire, a video was created to explain the tool. To simplify understanding in the video, we use a simple story where we use the BIM tool in a context. In a previous study we had already presented a video to test a concept, this technique proved to be useful and well accepted by the participants [9]. A team of experts wrote the script, filmed the scenes and edited the video. When finished, it was uploaded to embed in part 2 of the survey (https://youtu.be/NR4-YyQIaeg).

The BIM tool appears as a functional prototype, was developed respecting usability heuristics. The simulation was run on Adobe XD and captured the video screen bringing a more realistic interaction, introducing files, pressing buttons and observing graphics. An audio was introduced in the edition, explaining what is being done at the same time.

In the first scene an architect is working in his studio, focused on his project. There are many sketches, materials and the environment seem disorganized. In this environment he can't work and is frustrated.

The second scene begins as a dream and a prototype of the program is presented.
In the last scene the architect returns to his first studio where he is alone and calls to get the program. In a perfect studio a work team uses the program and discusses the ideas of the projects they are working on.

2.3 Data Analysis

After exporting the data, they were inserted into the IBM SPSS (Statistical Package for Social Sciences) software to perform the statistical analysis.
With the Likert 1-7 scale we will extract the percentages of responses, mean, median and standard deviation from the constructs. This analysis will show the response tendencies of the architects.
Cronbach's alpha assesses whether the designed test measures the variable of interest. It's interesting test the reliability of the Likert Scale multiple question survey. Cronbach's alpha greater than 0.7 suggests an acceptable internal consistency.
With the factorial analysis we reduce many variables into fewer numbers of factors. Factors represent the relationships between the various constructs of the survey. This grouping will help us to assemble the model for acceptance of the BIM tool.

2.4 Sample

In total, 102 questionnaires were collected for analysis. The gender ratio corresponds to 57 men 55.9%) to 45 women (44.1%). The minimum age was 21 years and the maximum age was 59 years, the mean was 33.8, with a median of 32.0 and a standard deviation of 8.2 years. The sample included 97 architects (95.1%) and 5 architecture students (4.9%). In the nationality factor we observe that 92 people are Portuguese (90.2%) and 10 Brazilians (9.8%).

3 Results and Discussion

We present table 1, shows the distribution of scores by participants for each question (N=102). The results are grouped by the cumulative percentage. Percentages are cumulated with response 1, 2 and 3 on the Likert scale (1 completely disagree – 7 completely agree) as the negative tendency, response 4 is the neutral response that does not agree or disagree with the sentence, and responses 5, 6 and 7 are considered as positive tendency.

Table 1. Distribution of scores for each question.

Constructs	Code	Percentage of responses 1,2 and 3	Percentage of response 4	Percentage of responses 5,6 and 7
Performance	PE1	16,7%	12,7%	70,6%
Expectancy	PE2	25,5%	15,7%	58,8%

	PE3	22,5%	18,6%	58,9%
Effort Expectancy	EE1	6,9%	16,7%	76,4%
	EE2	5,9%	19,6%	74,5%
	EE3	7,8%	22,5%	69,7%
Social Influence	SI1	21,6%	22,5%	55,9%
	SI2	11,8%	16,7%	71,5%
	SI3	16,7%	14,7%	68,6%
Facilitating Conditions	FC1	12,7%	26,5%	60,8%
	FC2	16,7%	17,6%	65,7%
	FC3	22,5%	28,4%	49,1%
Hedonic Motivation	HM1	20,6%	36,3%	43,1%
	HM2	17,6%	32,4%	50,0%
	HM3	18,6%	32,4%	49,0%
Behavioral Intention	BI1	13,7%	21,6%	64,7%
	BI2	14,7%	19,6%	65,7%
	BI3	20,6%	22,5%	56,9%

Analyzing table 1 we can see a tendency to the right, that is, the answers 5, 6 and 7. Recalling our main objective of this study, we want to know if the BIM tool will be accepted by architects. The Behavioral Intention construct shows us that there is a mean between 4,7 and 5 in the questions, although it's a positive response, it doesn't indicate the best intention to use the tool. We also noted a lower agreement on the questions of variable Hedonic Motivation, we want to know if the use could be fun, enjoyable or exciting. The neutral answer may be because they never used the tool and can't understand with the video or because the tool presented doesn't seem very different from others, they already use it in work. The tool should be used in a serious work situation, architects don't see it as something with so much fun. We also observed the coded question FC3, comparing with the other questions of the construct Facilitating Conditions this presented a lower mean and a lower positive trend. Most people think have the necessary knowledge to use the tool (FC1) and the tool is compatible with other technologies they use (FC2), but most of them don't believe that other people would help them if they had difficulty using the tool (FC3).

To measure reliability or internal consistency, Cronbach's alpha was applied to verify if the questionnaire measures what it should, in our case the acceptability of the tool by the architects. In our case Cronbach's alpha is 0.933, higher than 0.9, indicates an excellent internal consistency. A high level of consistency for this specific sample shows that the questionnaire is reliable and accurately measures the variable of interest.

A factorial analysis was performed to identify the minimum number of factors that represent the relationships between the various items of the questionnaire. The Keyser-Meyer-Olkin test had a value of 0.888 revealing that the analysis of the main components is good. Table 3 shows the factor matrix after varimax rotation. Factor extraction determined three factors.

Table 2. Factor matrix after Varimax rotation

Constructs		Rotated Component Matrix		
		Factor 1	Factor 2	Factor 3
Performance Expectancy	PE1	**0,802**		
	PE2	**0,804**		
	PE3	**0,754**		
Effort Expectancy	EE1		**0,847**	
	EE2		**0,881**	
	EE3		**0,825**	
Social Influence	SI1			**0,795**
	SI2			**0,787**
	SI3	0,408		**0,683**
Facilitating Conditions	FC1		**0,770**	
	FC2	0,407	**0,553**	
	FC3	0,414	**0,623**	
Hedonic Motivation	HM1	**0,832**		
	HM2	**0,825**		
	HM3	**0,891**		
Behavioral Intention	BI1	**0,878**		
	BI2	**0,897**		
	BI3	**0,893**		

The first factor is responsible for 49.4% of the variance and consists of Performance Expectancy, Hedonic Motivation and Behavioral Intention. These variables indicate the intended use of the tool. The nature of the variables in this factor will be called Tool Use. The second factor, responsible for 14.4% of variance, is Effort Expectancy and Facilitating Conditions. These variables are related to the ease/effort perspective and conditions for using the application. This factor will be called Conditions of Use.
The third and last factor, responsible for 9.4% of the variance, is Social Influence. As this factor consists of one variable, we will keep its name Social Influence.
This factor labeling can be subjective and is presented as a suggestion analyzing the variables contained in each group. These factors are associated with user acceptance of the tool.

4 Conclusions

The study reported results of accepting the use of a BIM add-on tool, using a video with a program usage scenario. The identification of the acceptance of this software at

an early stage of the development of the Ren4EEnIEQ project will justify the costs involved in the application development. For our sample, AutoCad is the most popular tool and should be considered in design solutions. We identified an agreement with the Behavioral Intention sentences: "I would like to use this tool in the future." with 64.7%; "I would like to use the tool in my work." with 65.7%; and "I would like to use the tool often." with 56.9%. However, we still have the remaining percentage of disagreement (between 13.7% and 20.6%) and with no preference (between 19.6% and 22.5%).
For future work we recommend the inclusion of other professionals, such as engineers working with BIM tools. Perhaps adding more information about the tool's functionalities would be an added value for the perception of use. We are also concerned with adding a variable for years of professional inexperience and not only if the participants are students or architects. It would be interesting to know if the architect works as a freelancer, and if he has worked in another country. We believe that considering these factors can affect the results positively.

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