# FROM CAD TO BIM: A NEW WAY TO UNDERSTAND ARCHITECTURE

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ABSTRACT

In recent years, and despite the effects of the economic crisis in the building sector, technicians involved in the architectural process had to adapt themselves to many changes, in search of new job opportunities. In this situation, traditional methods imposed by computer-aided design (CAD) in the development of new projects have evolved towards the use of Building Information Modelling (BIM) methodologies, enabling the control of different aspects such as the design, construction and monitoring of a building; the implementation of this new approach has meant essential updating of construction professionals towards a new global coordination paradigm throughout the complete life cycle of a building. In order to analyse these demanded skills acquired by technicians with previous experience both in traditional CAD systems and BIM environments, a study has been carried out to determine (by comparison) the outstanding aspects about the use of BIM systems, taking into account the modelling process. To do so, a simple practical exercise of modelling using both AutoCAD and Revit software has been carried out with the participation of students and professionals within the building sector. Necessary data were obtained and later evaluated through simple regression considering the time dedicated to the modelling resolution; also, different variance analyses were conducted to identify alterations between the different categories and groups considered, taking into account factors such as gender, having a previous university degree or not, years of experience with CAD or BIM software, type of academic qualifications or having attended previous training courses (among others).

*Keywords: CAD, BIM, architecture, Revit, comparison.*

## 1 INTRODUCTION

Throughout history, the methods of graphically documenting an architectural project have evolved and adapted to the new needs in the construction sector. In this way, in the last 40 years we have moved from fully manual documentation to the introduction of digital design in construction, first by the emergence of computer-aided design technology (CAD) and, later on, by the use of Building Information Modelling technology (BIM) for the design, monitoring and control of buildings during their whole life cycle.

For this reason, it is possible to classify the generation of documentation for the construction of buildings in three main phases: the manual phase, the digital phase and the BIM phase. The step accomplished from one to the other does not happen immediately throughout history, as it necessarily exists a period of adaptation between each of them, to be reached by every agent involved in the construction sector.

Thus, until the 1980s the design of the architectural project was carried out manually and, although in 1982 *Autodesk* created the first version of CAD for PC, several years had to pass by until the digital phase practically replaced the manual phase in the design of a building; this change finally happened in 1997, with the appearance of R14 version of AutoCAD [1].

This paradigm shift, from manual to digital practices, has evolved over the years, improving computer design processes and making them more efficient. In this context, Scheer [2] suggests that the increase in the use of BIM and computational design is due to an improvement in the economy of modern construction, since it allows a better prediction of the performance of buildings (thermal comfort, energy efficiency, etc.) and an increase of

WIT Transactions on The Built Environment, Vol 169, © 2017 WIT Press
www.witpress.com, ISSN 1746-4498 (on-line)
doi:10.2495/BIM170051

business productivity (better communications, easy information sharing, etc.). This situation can lead to excessive reliance on digital tools, leaving aside the physical act of drawing and the cognitive processes of design needed for architecture conceptualization [2].

### 1.1 From manual design to digital CAD design

The transition from the manual design process to the digital project was a technological advance in the development and creation of architectural environments. CAD systems used geometry based on specific coordinates, obtaining different representation elements susceptible to manual changes; because of this, the introduction of computer-aided design ensured better results and greater efficiency in the constructive documentation generated for an individual project. At this point, the most used software has been AutoCAD; a program originally developed for 2D modelling, which was subsequently implemented with 3D design tools.

Nowadays, the implementation of CAD tools is absolutely generalized in the daily work for all agents involved in the construction sector, considering AutoCAD the most popular CAD software among European architects for the development of building projects [3]. However, it is necessary to emphasize that the proficiency level for the use of these tools has been limited in many cases, since the usual way to proceed is very similar to traditional manual methods: projects are based on the use of literal representation of independent digital models (at both graphic and numerical levels) that, later on, are able to be manually-modified depending on the particular user who handles the tool.

Therefore, in the updating process from the manual phase to the digital phase, we moved from a representation through manual techniques to the use of more technical CAD tools but following very similar methods (if not almost identical) in the way of thinking about the architectural project. Moreover, considering the difficulty found to monitor and control the modifications made with this technology, CAD software has not come to completely minimize the appearance of design errors in the project coming out during the construction phase (even despite the increase of dedication hours).

### 1.2 From CAD to BIM

In recent years, the BIM technology has been a breakthrough in the process of architectural design, allowing an improvement of a 3D environment with a detailed analysis of the construction process before completing the real building, and also enabling to check interferences between elements in the model prior to onsite execution thanks to continuous queries and updates of the design [4]. The progress in the generation of this type of tools and methodologies has allowed the creation of new packages and applications to manage the construction process in a coordinated way, involving an improvement of results and contributing to the reduction of final costs.

Parallel to this technological evolution, there have also been changes in the way of conceiving the construction process. Today, there is a broader project concept where technicians involved in the sector also participate throughout the whole life cycle of the building; in this global process, BIM technology allows to coordinate and control the complete evolution of each construction [5]. These BIM tools are increasingly being used by building agents, enabling productivity to increase [6]; however, just as the implementation of CAD took several years to be generalized in the companies of the sector, the implementation process of BIM is also being gradually developed. In fact, we have to go back several years ago to find the first applications of this new technology, considering the purchase of the company *Revit Technology* by *Autodesk* in 2002 as the beginning of the consolidation of the concept called "Building Information Modelling" [7].

Over the last 15 years, both technologies have co-existed; however, it is true that little by little BIM technology is replacing CAD. This transformation process must be continuous from the beginning of the project, always allowing to redirect the planning of the design and to assimilate the changes step by step in a regular way [8]. It has been found that the use of BIM technologies in the field of architecture is assuming a qualitative professional momentum, giving greater precision to the project in all levels [9]. In the case of architectural offices, the main reasons for the increasing use of BIM technologies when drafting construction projects are: the improvement of quality in the design, the ease of modification and presentation of the project, the reduction of errors and the decreased of delivery terms [10].

## 2 MAIN OBJECTIVE

In order to analyse the level of knowledge and implementation of the BIM technology as a new tool for the generation of the architectural projects (versus traditional CAD tools), a study of modelling a simple architectural project in a design phase has been carried out.

The main objective of the present study is to compare the most commonly applied technologies in current projects; On the one hand, a CAD software (AutoCAD, version 2016) and on the other hand, a BIM software (Revit, version 2016), both from Autodesk. The comparison has been made considering the graphic documentation of the project, obtained during the modelling phase, in order to get necessary data for later verification and, after analysis, to draw conclusions about the use of both programs.

To do so, a simple practical exercise has been carried out using AutoCAD and Revit, with the participation of students and professionals of the building sector. A simple regression analysis about the time spent on the modelling resolution was performed with the collected data, as well as an analysis of variance to identify the differences between the categories and groups considered, taking into account several factors such as gender, to have or not to have a university degree, years of experience in the use of the software, academic degree or the previous completion of training courses, among others.

## 3 MATERIALS AND METHODS

In the research, a study of the time devoted to the modelling phase for a basic architectural project is carried out, comparing the results obtained by using BIM technology opposite to CAD. To this end, a group of students and professionals (mainly architects and building engineers) have been selected to develop a simple project of a detached house (one level) using both technologies. The proposed exercise is the implementation of a single-family housing consisting of living room, kitchen, bathroom and two bedrooms. The plan to be defined shows the representation of the interior partitions and exterior walls, interior and exterior carpentries, furniture, sanitary equipment, floors and net floor areas of the rooms to be modelled. For this purpose, a practical session was held with the participation of 19 people who modelled the selected housing with AutoCAD and Revit programs (Fig. 1).

Before the beginning of the practical session, the attendees completed a survey to provide certain data related to the use of CAD and BIM in order to compare them, later on, with the time results obtained in the practical exercise. All participants were provided with a link to an online questionnaire about their academic situation (student or professional in the sector) and their previous experience in the management of the software analysed.

On the one hand, a dimensioned drawing of the building was printed on paper and distributed among the attendees as a basic documentation prior to the realization of the comparative exercise; also the necessary instructions to carry out the practice with the greatest uniformity among all participants were provided. In order to facilitate the resolution of the practical exercise, information about 2D blocks and layers distribution of interior and exterior walls were already inserted in a template (DWG format) and delivered as initial documentation for the CAD test. On the other hand, a selected list of the families (furniture, doors and windows) to be used in each room (bedrooms, bathroom, kitchen and living room) was given in a shared folder for the BIM test, so as to optimize the modelling time and give uniformity to the final results.

After the delivery of the initial documentation, the test was started, timing the time needed by each participant to complete the assignment. As they ended the exercise in AutoCAD and Revit, each of the attendants delivered the final file (.dwg and .rvt) for verification (Fig. 2).

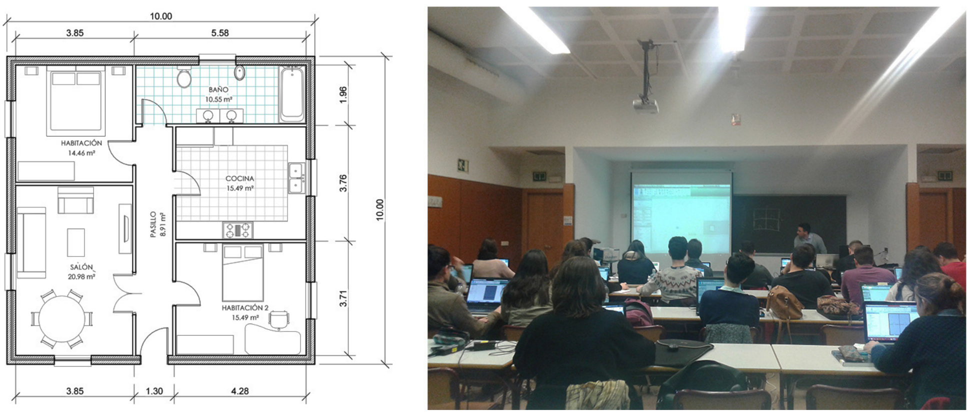


Figure 1: Main floor plan of the project and selected participants during the exercise. *(Source: authors.)*

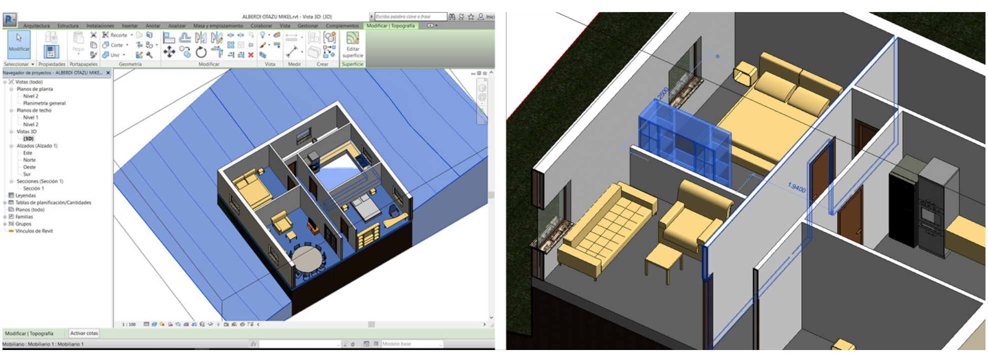

Figure 2: Revit exercise from a participant. *(Source: Mikel Alberdi Otazu.)*

## 3.1 Description of the measuring instrument and the participants

The data collection was structured in several sections considering sociodemographic data, information about professional activity, as well as previous use and training received in software related to architecture and engineering. In total, 10 questions were answered, most of them structured with two or three possible answers, complementing the data of each participant with the time spent (minutes) to solve the exercise through CAD and BIM software.

The following lines describe the variables used in the analysis of the survey to the 19 participants. In Table 1 we provide the coding and description of each answer in the survey, and the recoding used for the dummy variables used in the regression.

Table 1: Variables, coding and frequencies of the data collected in the survey.

| VARIABLE | SURVEY DATA | | RECODIFICATION FOR REGRESSION | |
|---|---|---|---|---|
| CAD_MINUTES | Continuous variable (minutes)<br>*M* = 55.0, *SD* = 20.0, *min.* = 33, *max.* = 104 | | | |
| BIM_MINUTES | Continuous variable (minutes)<br>*M* = 79.2, *SD* = 22.6, *min.* = 43, *max.* = 120 | | | |
| GENDER | 0 = Male | 11 (57.9%) | 0 = Male | 11 (57.9%) |
| | 1 = Female | 8 (42.1%) | 1 = Female | 8 (42.1%) |
| AGE | Continuous variable (years)<br>*M* = 28, *SD* = 5.8, *min.* = 21, *max.* = 43 | | | |
| STUDIES | 0 = BE | 10 (52.6%) | 0 = BE + CE | 11 (57.9%) |
| | 1 = ARC | 8 (42.1%) | 1 = ARC | 8 (42.1%) |
| | 2 = CE | 1 (5.3%) | | |
| ACT_PROFFESIONAL | 0 = Activity no | 9 (47.4%) | 0 = Activity no | 9 (47.4%) |
| | 1 = Activity yes | 10 (52.6%) | 1 = Activity yes | 10 (52.6%) |
| CAD_USE | 0 = University | 8 (42.1%) | 0 = University | 8 (42.1%) |
| | 1 = Professional | 11 (57.9%) | 1 = Professional | 11 (57.9%) |
| | 2 = Not used | 0 (0.0%) | | |
| BIM_USE | 1 = University | 7 (36.8%) | 1 = University | 7 (36.8%) |
| | 2 = Professional | 0 (0.0%) | | |
| | 0 = Not used | 12 (63.2%) | 0 = Not used | 12 (63.2%) |
| CAD_TRAINING | 0 = Self-taught | 10 (52.6%) | 0 = Self-taught | 10 (52.6%) |
| | 1 = Courses | 9 (47.4%) | 1 = Courses | 9 (47.4%) |
| | 2 = No training | 0 (0.0%) | | |
| BIM_TRAINING | 0 = Self-taught | 4 (21.1%) | 0 = Self-taught | 4 (21.1%) |
| | 1 = Courses | 15 (78.9%) | 1 = Courses | 15 (78.9%) |
| | 2 = No training | 0 (0.0%) | | |
| CAD_YEARS | 1 = <5 years | 5 (26.3%) | 0 = < 5 years | 5 (26.3%) |
| | 2 = 5–10 years | 10 (52.6%) | 1 = ≥ 5 years | 14 (73.7%) |
| | 3 = 10–15 years | 4 (21.1%) | | |
| | 4 = Not used CAD | 0 (0.0%) | | |
| BIM_YEARS | 0 = Not used BIM | 7 (36.8%) | 0 = Not used BIM | 7 (36.8%) |
| | 1 = 1 year | 9 (47.4%) | 1 = ≥1 year | 12 (63.2%) |
| | 3 = > 1 year | 3 (15.8%) | | |

Note: coding, text descriptor of the answer, number of subjects and frequencies.


www.witpress.com, ISSN 1746-4498 (on-line)

- CAD_MINUTES: time spent (in minutes) to complete the exercise using a CAD software (AutoCAD).
- BIM_MINUTES: time spent (in minutes) to complete the exercise using a BIM software (Revit).
- GENDER: gender of the participant, male or female.
- AGE: age of the participant, it has not been used as an analysis variable.
- STUDIES: in case of having finished a university degree Architecture (ARC), Building Engineering (BE) and Civil Engineering (CE). Since there was only one individual for Engineering, it was decided to group it together with Building Engineering (BE).
- ACT_PROFFESIONAL: indicates whether the participant performs a professional activity or not.
- CAD_USE: main area in which the CAD software is used (university, professional or not used).
- BIM_USE: main area in which the BIM software is used (university, professional or not used).
- CAD_TRAINING: the way how CAD training has been acquired, on a self-taught basis, through specific training courses or without previous training.
- BIM_TRAINING: the way how BIM training has been acquired, on a self-taught basis, through specific training courses or without previous training.
- CAD_YEARS: number of years using CAD software, whether in the professional or academic field. It was necessary to recode this variable due to the lack of diversity in the answers obtained.
- BIM_YEARS: number of years using BIM software, whether in the professional or academic field. It was necessary to recode this variable due to the lack of diversity in the answers obtained.

## 4 RESULTS AND DISCUSSION

The results chapter is structured in two sections; the first one analyses the influence of each variable of the model to estimate or predict the time spent to develop the BIM model, by using a least squares regression techniques. In the second section, an analysis of the variance of a factor (One-way ANOVA) is performed to identify if there are differences between the categories or groups of each of the dichotomous variables.

### 4.1 Regression analysis

The time data used to solve each model show the existence of a statistically significant positive correlation between the time spent in the CAD model and in the BIM model ($r = 0.833$, $p < 0.01$, $n = 19$). A simple regression analysis estimates that the model accounts for 67.6% of the variability ($R^2_{adj} = 0.676$, $n = 19$), using the following formula:

$$\text{BIM\_MINUTES} = 0.94 \times \text{CAD\_MINUTES} + 27.3 \text{ (time in minutes).} \quad (1)$$

This means that high values of time dedicated to BIM correspond to high values of time dedicated to CAD; the opposite is also true. This result shows the complexity or simplicity of the exercise since, regardless of the computer program used, the time to be devoted to solving the problem has the same sign. However, the productivity obtained with BIM applications is much greater, since the time invested in the resolution of the exercise allows obtaining a greater number of resources in the form of 2D plans, 3D drawings or materials schedules, among others.

In spite of the small size of the sample, and in order to evaluate if the 9 dichotomous variables and CAD_MINUTES are relevant to estimate the time spent in the elaboration of the BIM model, a multiple regression analysis is performed by an stepwise method, transforming to natural logarithm the dependent variable (BIM_MINUTES) in order to make a log-value model. As Álvarez points out [11], it is a widely used method in which the selection process is initiated by first including the independent variable that is most correlated (in absolute value) with the dependent variable, provided that the coefficient of regression corresponding to the variable has a level of significance less than 0.05. Then, the variable with the highest partial correlation with the dependent variable is introduced into the equation and it is verified that it meets the established tolerance criteria. The process continues until there are no variables that improve the fit. If the regression coefficient obtained by introducing a new variable exceeds the significance level of 0.1 in any of the steps, the variable is eliminated from the model.

The model obtained meets a minimum of robustness and significance in the estimated parameters that makes it acceptable to perform inference. The Durbin–Watson statistic is 2.37, suggesting absence of autocorrelation in the residual [12], [13]; the $F$ statistic ($F_{0.05\,(2,16)} = 18.6$, $p < 0.001$) obtained in the ANOVA analysis suggests that at least one of the regression variables contributes significantly to the model; the adjusted coefficient of determination $R^2_{adj}$ (0.662) indicates a high explanatory capacity.

Table 2 shows the coefficients and significance levels of the multiple regression model, where only two independent variables are statistically significant, CAD_MINUTES and GENDER. The interpretation of the log-value model suggests that each additional minute in CAD_MINUTES implies a 1.1% longer time to perform the BIM model, and being female implies a 17.7% more time. This latter result does not imply that women have less skills than men, as it may be due to other factors as the reduced size of the sample or other variables that the model has not captured, such as being more perfectionist or thoughtful, having less previous experience in BIM software, etc. In fact, it is observed that the majority of women affirm not to use BIM in their university and / or professional field.

$$Log\ (\text{BIM\_MINUTES}) = 0.011 \times \text{CAD\_MINUTE} + 0.177 \times \text{GENDER} + 3.654. \quad (2)$$

Table 2: Results of the multiple regression model.

| | Unstandardized coefficients | | Standardized coefficients | | |
|---|---|---|---|---|---|
| Coefficients | B | Std. error | Beta | *t* | *Sig.* |
| (Constant) | 3.654 | 0.119 | | 30.777 | 0.000 |
| CAD_MINUTES | 0.011 | 0.002 | 0.761 | 5.540 | 0.000 |
| GENDER | 0.177 | 0.078 | 0.310 | 2.259 | 0.038 |

Note: Dependent variable log(BIM_MINUTES).

## 4.2 Analysis of variance

In order to identify if there are differences in the mean time devoted to solving the CAD and BIM models, several contrasts for the analysis of the variance have been made (Table 3). The One-way ANOVA is a statistical tool that allows to identify if two or more groups of a population differ between them or if they are similar; in other words, it checks whether there are significant differences in a quantitative variable due to the mean effect of the different treatments or levels in the studied factor (in this case, in each of the dummy variables).

By means of this analysis, a statistic called $F$ is calculated, which shows the degree of similarity between the means being compared. The $F$ statistic is interpreted in a similar way as it is done with the $T$ statistic in the *Student t-test*. If the critical level associated with the $F$ statistic (i.e. if the probability of obtaining values as obtained or greater) is less than 0.05, the equality of means hypothesis will be rejected, concluding that not all the population means compared are equal. In the case of not rejecting the equality hypothesis ($p > 0.05$), it will not be possible to establish that the compared groups differ in their population mean, so that equal means are considered between the groups. The bilateral statistical hypothesis is as follows:

$$H_0: \mu_1 = \mu_2 = \ldots = \mu_k \quad \text{(the means of the groups are equal, for } p > 0.05\text{)}$$
$$H_a: \mu_i \neq \mu_j \quad \text{for at least one pair } i, j \quad \text{(means are different, for } p \leq 0.05\text{)}$$

For the case of the STUDIES variable, it is observed the existence of statistically significant differences in the time devoted to CAD drawing (CAD_MINUTES). Since homogeneity of variances between groups is not verified, the robust tests of equality of the Welch and Brown-Forsythe means (Asymptotically $F_{(1,13)} = 8.245$, $p < 0.013$) are used, proving to be statistically significant and suggesting to confirm the previous result and to reject the null hypothesis of equality of means between the groups.

It is observed that the group of BE+CE (Building Engineers and Civil Engineers) shows a mean of $M = 63.73$ minutes ($SD = 21.96$, $n = 11$) to perform the CAD drawing, while the ARC group (Architects) devotes $M = 43.13$ minutes ($SD = 7.83$, $n = 8$). This situation can show a greater specialization of the architects in CAD, compared to Building Engineers and Civil Engineers.

On the other hand, there are no significant differences in the time mean for the resolution of the BIM model (BIM_MINUTES), which suggests a lower specialization in BIM tools by all the comparison groups.

Table 3: ANOVA tests for each dummy variable.

| VARIABLE | CAD_MINUTES | BIM_MINUTES |
|---|---|---|
| GENDER | $F = 0.047$, $p = 0.831$ (*) | $F = 1.494$, $p = 0.238$ (*) |
| STUDIES | $F = 6.367$, $p = 0.022$ | $F = 2.846$, $p = 0.110$ (*) |
| ACT_PROFFESIONAL | $F = 0.330$, $p = 0.573$ (*) | $F = 0.201$, $p = 0.660$ (*) |
| CAD_USE | $F = 0.339$, $p = 0.568$ (*) | $F = 0.173$, $p = 0.683$ (*) |
| BIM_USE | $F = 0.082$, $p = 0.778$ (*) | $F = 0.052$, $p = 0.823$ (*) |
| CAD_TRAINING | $F = 0.509$, $p = 0.485$ (*) | $F = 0.397$, $p = 0.537$ (*) |
| BIM_TRAINING | $F = 0.239$, $p = 0.631$ (*) | $F = 0.019$, $p = 0.893$ (*) |
| CAD_YEARS | $F = 1.987$, $p = 0.177$ | $F = 2.185$, $p = 0.158$ (*) |
| BIM_YEARS | $F = 0.387$, $p = 0.542$ | $F = 0.041$, $p = 0.842$ (*) |

Note: $gl_1 = 1$, $gl_2 = 17$, $n = 19$, (*) the homogeneity of variances between groups is fulfilled.

## 5 CONCLUSIONS

The analysis was based on a case study carried out with 19 participants, composed of university students and professionals of the construction sector. A survey-type instrument was used to collect the initial information; also, a control of the time used to solve the exercise using AutoCAD and Revit programs was measured for each participant. This research has quantified the correlation between the time spent in the development of an architectural project using CAD and BIM systems, specifically in the design phase. In addition, we have analysed possible causes or factors that may influence the process of implementation of BIM methodologies versus traditional CAD systems in the earliest steps of a project.

The results obtained show a high positive correlation between the time needed to elaborate both CAD and BIM models; it is estimated by simple and multiple linear regression techniques that, for each additional minute to develop the CAD model, 1.1% more time is needed to perform the BIM model. This result indicates that implementing BIM in design phases of the architectural project does not represent a high increase of time.

In identifying possible factors that may influence the BIM implementation process over traditional CAD systems, no differences were detected between the categories of the variables under analysis. These results may be due to the lower specialization and track records of the participants in the management of BIM environments against CAD. It has been observed that the participants had extensive experience in CAD environments, both in the academic and professional fields, while BIM systems have been recently implemented, in general terms, in academic areas.

Finally, it is important to mention that, in the analysis developed, it has not been possible to quantify time saving related to the greater versatility of the BIM environments in terms of project´s modifications, since, after the realization of a specific modification in the model, views, plans or schedules are automatically and immediately updated; CAD models are not able to achieve these results and uses have to manually redraw modifications in every detail, plan, etc. Also, a more detailed analysis of the benefits obtained from the correct definition of the BIM model would be interesting in future research, for example to identify interferences between elements; thus, it is estimated that it would allow time savings in other phases of the project, although they would require a greater development and dedication in the initial phases [14].

## REFERENCES


[1] Guindis, E., *Up and Running with AutoCAD 2016: 2D and 3D Drawing and Modeling,* Elsevier: Amsterdam, 2015.

[2] Scheer, D.R., *The Death of Drawing: Architecture in the Age of Simulation*, Routledge: New York, 2014.

[3] Arch-Vision BV, *AutoCAD is the most popular CAD software among architects in Europe*, 2011, Rotterdam. Online, http://www.arch-vision.eu/persberichten/AutoCAD-is-the-most-popular-CAD-software-among-architects-in-Europe.pdf. Accessed on: 15 Mar. 2017.

[4] Hernández, L.A., Towards the digital project. *EGA, Revista de Expresión Gráfica Arquitectónica*, **18**, pp. 270–279, 2011. Doi: http://dx.doi.org/10.4995/ega.2011.1112.

[5] Eastman, C., Teicholz, P., Liston, K. & Sacks, R., *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors,* Wiley Publishing Inc.: Indianapolis, 2011.

[6] Sacks, R. & Barak, R., Impact of three-dimensional parametric modeling of buildings on productivity in structural engineering practice. *Automation in Construction*, **17**(4), pp. 439–449, 2007. Doi: http://dx.doi.org /10.1016/j.autcon.2007.08.003.

[7] Davis, P., *Introducing Autodesk Revit Architecture 2012*, Wiley Publishing Inc.: Indianapolis, 2011.
[8] Piedecausa-García, B., Mateo-Vicente, J.M. & Pérez-Sánchez, J.C., Enseñanza de sistemas BIM en el ámbito universitario. *Proceedings EUBIM 2015 Congreso Internacional BIM/Encuentro de Usuarios BIM*, pp. 93–100, 2015.
[9] NBS-RIBA, *National BIM Report.* RIBA Enterprises Ltd., 2014-2015-2016.
[10] Souza, L., Amorim, S. & Lyrio, A., Impactos do uso do BIM em escritórios de arquitetura: Oportunidades no mercado imobiliário. *Gestão & Tecnologia de Projetos*, **4**(2), pp. 26–53, 2009.
[11] Álvarez C.R., *Estadística multivariante y no paramétrica con SPSS: aplicación a las ciencias de la salud*, Ediciones Díaz de Santos S.A.: Madrid, 1995.
[12] Montgomery, D.C., Peck, E.A. & Vining, G.G., *Introduction to Linear Regression Analysis*, 5th ed., John Wiley & Sons Inc.: New Jersey, 2012.
[13] Yan, X. & Gang-Su, X., *Linear Regression Analysis: Theory and Computing*, World Scientific Publishing Company Pte. Limited: Singapore, 2009.
[14] Chi, H.L., Wang, X. & Jiao, Y., BIM-enabled structural design: Impacts and future developments in structural modelling, analysis and optimisation processes. *Archives of Computational Methods in Engineering*, **22**(1), pp. 135–151. Doi: http://dx.doi.org/10.1007/s11831-014-9127-7.