BIM and sustainability concepts in construction projects: A Case Study

Bahriye Ilhan
Research Assistant
Istanbul Technical University
Turkey
ilhanba@itu.edu.tr

Hakan Yaman
Associate Professor
Istanbul Technical University
Turkey
yamanhak@itu.edu.tr

Summary

Even though the need of integration of BIM and sustainability as emerging concepts in the construction sector has been discussed, there are some barriers to a functional inclusion. This paper focuses on the current state of BIM in sustainability as well as other factors affecting the success of sustainable construction projects by performing interviews with the Turkish architectural firms participated in certificated sustainable projects in order to find out the key indicators for better integration solutions. Fuzzy-set qualitative comparative analysis (fsQCA) is used for evaluating the results due to its availability to provide the relations between the factors examined. Each impact of the variables on the sustainable projects is discussed in the conclusion.

Keywords: Building Information Modeling, BIM, fsQCA, integration, sustainable construction.

1. Introduction

Building Information Modeling (BIM) and green building market are the two current and growing movements in the architecture, engineering and construction (AEC) industry [9]. BIM, one of the most important developments promising in the construction sector, is a new approach to design, construction, and facility management in which a digital representation of the building process is used to facilitate the exchange and interoperability of information in digital format [15]. It is a methodology to manage essential building design and project data in digital format throughout a building's life cycle. One of the key advantages of BIM over drawing methods, either manual or computer-aided (coordinate-based software, knowledge-based or object oriented systems), is its ability to prevent possible conflicts during construction process by providing accurate project drawings and construction documents on time and fast. Moreover, BIM provides users with a consistent method of conveying project information, which prevents errors or conflicts caused by lack of coordination within the project teams. BIM is developed for the needs of collaboration, getting improved outputs, minimising the risks, time loss and cost. It also aids in the development of buildings less harmful to the environment in addition to providing better visualisation and project integration.

The term BIM was coined in the 1970s by Charles Eastman and has been used in academia in various studies [4, 5 and 8]. The importance of design and construction integration has increasingly been realised in recent years and the value of BIM technology has been understood since the early 2000s in the construction sector and in academic studies related to construction. It has also been developed by computer-aided design (CAD) suppliers such as Autodesk, Bentley, Nemetschek and Graphisoft.

The strong growth of the green building market can encourage BIM adoption in the design and construction industry [10]. Moreover, their integration has a great impact and importance on sustainable construction. However, it is difficult to mention about a thoroughly integration in the

current situation due to lack of measured sustainable strategies' direct access into BIM models. Data needs to be exported to another application or imported from a data source [9]. In some cases a team may need to import information to the BIM model from an outside source, such as a database of weather data or material properties. Better and more seamless integration between BIM and sustainable design will come with time as the industry continues to standardise file formats, as data sets are developed, and as owners, clients, and designers begin to demand more from application developers [9].

Accordingly, the research presented in this paper focuses on the impact of BIM usage in sustainable construction projects' success in order to provide a basis for the integration of BIM and sustainability. The main purpose of the study is to determine the state of completed sustainable construction projects. This is achieved via conducting semi-structured interviews with the participants involved in the design process of the sustainable construction projects. The findings are considered to be useful indicators for the integration of BIM with standards of sustainable construction.

2. Sustainability and green building rating systems

The sustainability concept has been frequently encountered in the construction sector as in many other industries over the last two decades. The term of green in building design and construction started with the formation of Building Research Establishment (BRE), the American Institute of Architects (AIA) Committee on the Environment (COTE) and the U.S. Green Building Council (USGBC) and in the early 1990s [9]. World Commission on the Environment and Development, also known as the Brundtland Commission (1897) defined sustainability in construction as:

Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs.

Moreover, when other factors such as global warming, pollution and rapid consumption of energy resources are taken into consideration, sustainability is becoming increasingly important in today's construction industry. Therefore, various stakeholders including research institutes, governments and other non-profit establishments have discussed the sustainable solutions. In this context, green building rating systems play a key role in the dissemination of sustainable projects. This section examines BRE Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED), giving a brief explanation of each system. The named criteria-based assessment and certification systems are addressed in this study due to their common usage in Turkey.

2.1 BREEAM

BREEAM, the oldest assessment method developed by BRE in the United Kingdom as a tool to measure a building's environmental performance, addresses wide-ranging sustainability issues and enables developers, designers and building managers to demonstrate the environmental credentials of their buildings to clients, planners and other initial parties [2].

While the original version of BREEAM was limited to the office buildings, it has been developed and is available in a range of building types including existing buildings. The main areas in the assessment system are Management, Health and Well-Being, Energy, Transport, Water, Materials, Waste, Land Use and Ecology, Pollution and Innovation (added in 2009 version) respectively. Credits are awarded in each area according to performance and then added together through a combined weighting process in order to rate the building on a scale of Pass, Good, Very Good, Excellent or Outstanding and finally a certificate is awarded to the project [9]. Furthermore, BREEAM International, BREEAM Europe Commercial and BREEAM Gulf are the other categories developed for using aside from the UK.

2.2 LEED

LEED was developed by USGBC in 1998 for the purpose of sustainable buildings via

measurement standards [14]. LEED system, initially introduced for new construction (NC), has been developed over time in various versions for different types of buildings such as LEED for Core and Shell Development (CS), Commercial Interiors (CI), Existing Buildings (EB), Homes (H), Schools (S), and Retail (R). Under the LEED-NC system, buildings are judged via a credit system in five categories of environmental performance and one additional area for innovative strategies, which are Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality and Innovation and Design [9]. The final score is obtained by adding the credits from each category to determine the level of certification awarded to the project. The LEED levels of certification are Certified, Silver, Gold and Platinum based on the points.

The process of certification can be said as the main difference between the two methods. While BREEAM trains assessors who assess the evidence against the credit criteria and report it to the BRE that validates the assessment and issues the certificate, there is a credit available if an accredited professional (AP) whose role is to help for gathering the evidence and advise the client, is used in LEED system [3]. The evaluation is examined and certification is issued by USGBS.

3. Fuzzy set – Qualitative comparative analysis (FSQCA)

As fuzzy set qualitative comparative analysis (fsQCA) is intended to evaluate the results, it is useful to mention about the analysis briefly.

The qualitative comparative analysis (QCA) is a set of systematic ways of studying causality in a simple data table of binary or ordinal variables which is mainly used in comparative research, or with qualitative data, or as part of case-study research methods [11]. Fuzzy set qualitative comparative analysis (fsQCA), on the other hand, is a software that uses combinatorial logic, fuzzy set theory and Boolean minimisation to work out what combinations of case characteristics may be necessary or sufficient to produce an outcome [7].

A data matrix, a simple qualitative table of data made up of rows and columns, is the data-handling mechanism. The cases are listed as rows where in the columns; case characteristics are not 'variables' in the usual sense, but degrees of membership of a defined category. The column elements can be binary (yes/no), ordinal, or scaled index variates. QCA is best suited for small to medium-N case study projects with between 3 and 250 cases. Following the data matrix, construction of a truth table is generated. While crisp-set QCA uses only binary variates for its truth table, fuzzy-set QCA also uses ordinal variates [for further details, see 7, 11, 12 and 13].

4. Background

4.1 State of research and practice

As an emerging trend, Green BIM has been increasingly discussed for more sustainable outcomes in various studies [for further details see, 6, 10 and 16]. An online survey designed by McGraw_Hill Construction for 2010 Green BIM Study is conducted with a range of industry professionals who use BIM tools to assess the level and scope of use of BIM tools to help achieve sustainability and/or building performance objectives as well as the expected level and scope of use in the future. The results of the study show that BIM is considered as an essential tool for green construction and expected in extensive use of green market in the near future. The report also makes a list of the areas that are key to the potential growth of Green BIM and its impact on the green building marketplace as follows: Software Integration, Integrated Output from Different Building Systems, Modeling Standards, Increasing Use of BIM for Small Green Retrofit Projects, Using BIM for Building Performance Monitoring and Verification and Greater Use of Integrated Design. On the other hand, EU-project STAND-INN addresses new manufacturing processes based on IFC standards [1] and performance-based standards for sustainable construction with objectives of creating new and more efficient business processes in the construction sector. The main objectives are to facilitate the integration of open standards into business processes, provide the integration of open standards into the design of new products and services and stimulate innovation through reference to standards in public procurement. Moreover, [16] proposes a 3rd

party web service relying on BIM as the information backbone to facilitate the LEED documentation generation and management.

4.2 Problem Statement and Objectives

Even though the importance of Green BIM is recognised in the literature, there are some barriers to the BIM adoption in sustainable construction such as lack of functional tools and complex structure of the existing tools. However, it is obvious that there is a need for integration of BIM and green building market. This study aims to examine sustainable construction projects for setting up a substructure to fill the gap of BIM integration with standards of sustainable construction by conducting a case study. In accordance with this purpose, having interviews with the firms carrying out the projects in question and getting their prescience are intended. Not only the importance of BIM usage is investigated but also other factors affecting the success of a sustainable construction project are addressed.

5. Methodology

For an effective response to the research objectives, the research methodology includes four main steps (Figure 1): (1) Preparing the main topics to be discussed and the questions, (2) Determining corresponding participants to conduct the case study and interview (sampling), (3) Performing the interviews and data collection and (4) Data analysis and evaluating the results.

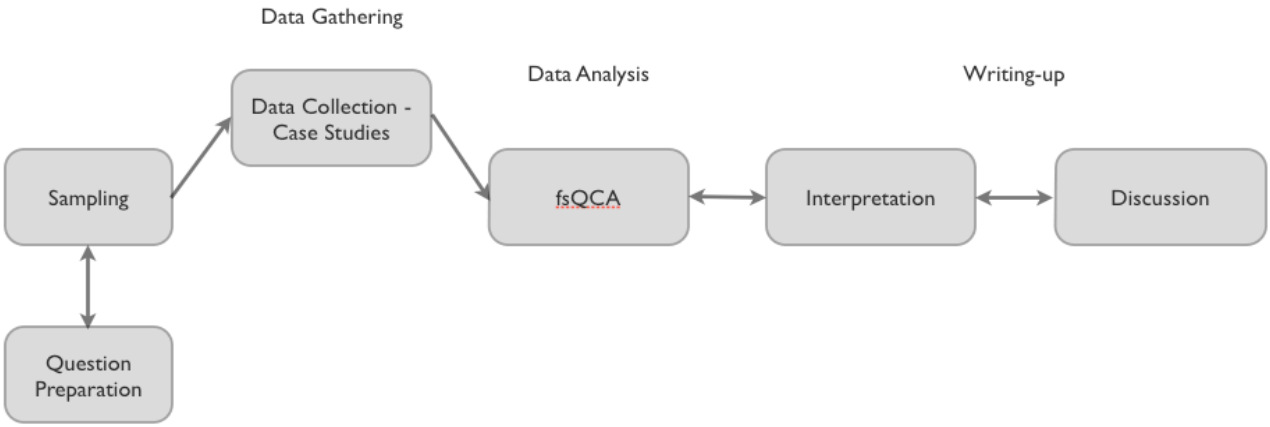


Fig. 1 Proposed method (Adapted from [11])

Firstly, the main topics and questions in order to examine the current state of sustainable construction projects in Turkey are determined. It is tried to avoid preparing very detailed, tedious and long questions, conversely, making a point of getting real data from more general but also key questions are intended. The questions vary from the sustainable project decision making to the future of sustainability in construction projects (Table 1).

The scope of the study is limited to the Turkish architectural firms that undertake the design of BREEAM and LEED certificated buildings in Turkey regardless of their ratings (levels) and scores. Therefore, the next step identifies these firms and determines the related participants. 35 firms are identified and 30 of them are contacted for interview request in total. 12 of them accepted to interview and/or answer the questions electronically. Following this step, the interviews are performed for gathering the data.

In the last step, the results obtained from the firms are used as the input data for fsQCA (http://www.compasss.org/). Firstly, the responses of each variable are calibrated (Table 2).

Table 1 The main topics of the questions

Topic	Research Question
Sustainable project decision	How is the sustainable project decision made? Who gives the decision? i.e. Owner demand or firm suggestion.
BIM usage	What is the current role of BIM in the sustainable construction projects? Are any BIM tools used in sustainable projects? If so, in which phases of the building production process?
The impact on fees	Is there any additional charge for generating sustainable and/or BIM projects?
Existence of a standard team	Is there any standard team for sustainable and/or BIM projects?
Sustainable data analysis	Which resources are used for selecting sustainable data?
Harmony of the data	How the harmonization between the data related to the sustainable construction and sustainable construction projects are provided?
Design process of sustainable construction projects	How does the design process progress? What are the differences from other projects?
Green consultancy service	How are the consultancy firms integrated to the building production process?
Project performance	What is the rate of your success?
Future	What is your prescience for operability? How do you see five years later?

Table 2 Calibration of the variables

Variable	Fuzzy Set	Values
BIMUsage PermanentTeam	4 Value Fuzzy-set	1= fully in 0.75 = more in than out 0.25= more out than in 0= fully out
DataAnalysis Harmonisation DesignProcess Consultancy ProjectSuccess	6 Value Fuzzy-set	1= fully in 0.90 = mostly but not fully in 0.70= more or less in 0.30= more or less out 0.10= mostly but not fully out 0= fully out

The collected data is converted into a table with the cases as rows and variables in the columns, presented in Figure 2. The variables are BIMUsage, PermanentTeam, DataAnalysis, Harmonisation, DesignProcess, Consultancy and ProjectSuccess.

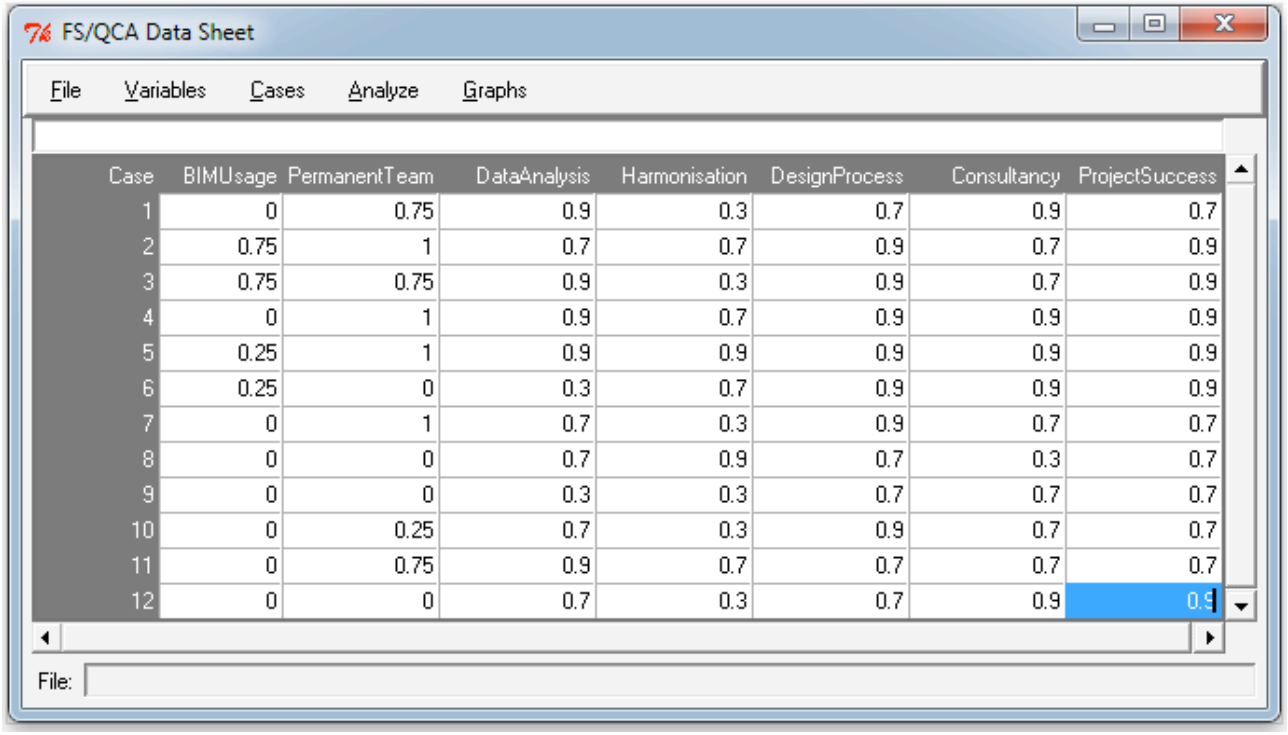


Fig. 2 Data matrix

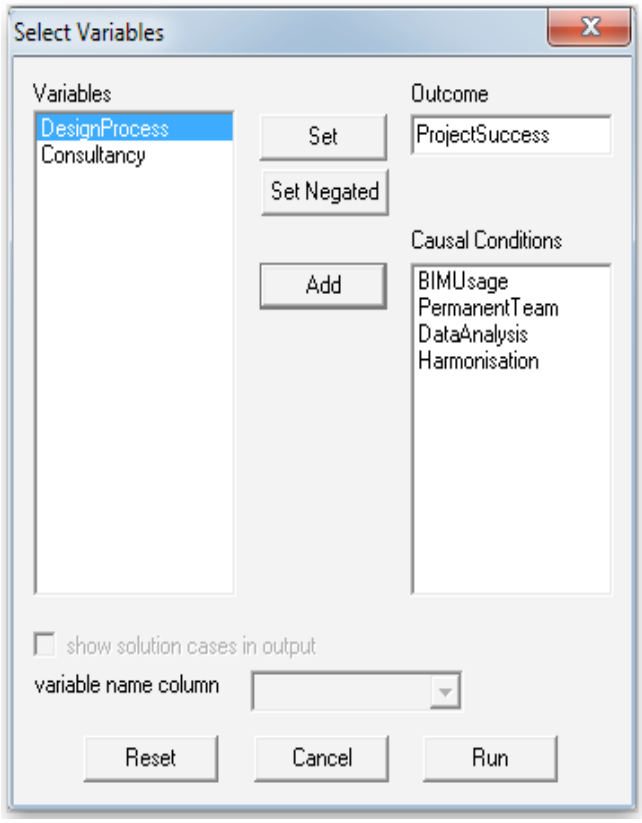


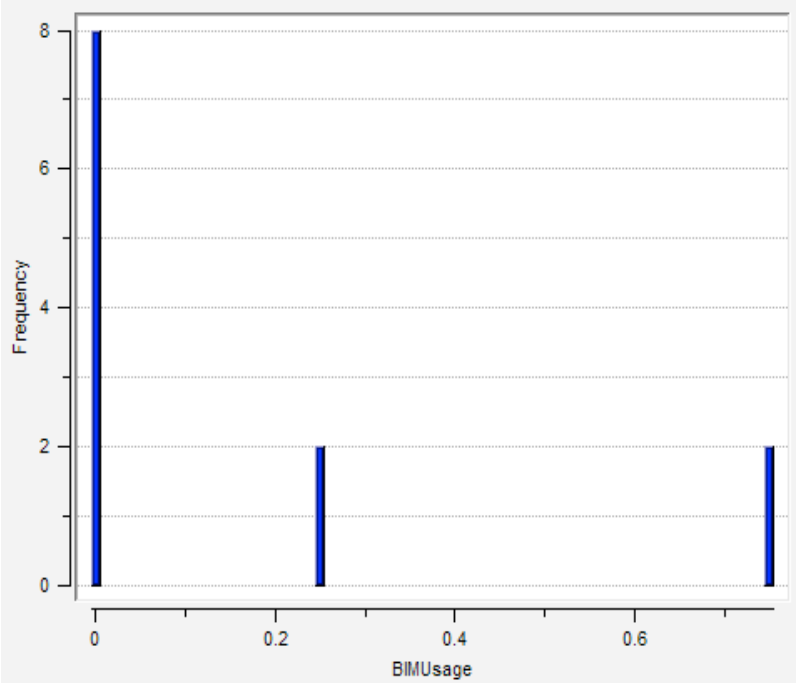
Fig. 3 Selection of the variables for Truth Table

Fuzzy Truth Table Algorithm is operated to construct the truth table. ProjectSuccess is set as the "outcome" and other variables are added to "casual conditions" (Figure 3).

In order to obtain the completed truth table, configurations are classified by removing the number of cases with smaller than 0.5 memberships in each configuration shown in the number column. Then, the configurations that are consistent subsets of the outcome from those that are not are distinguished. Values below 0.75 in the consist column indicate substantial inconsistency. Therefore, 1 is entered to ProjectSuccess columns that match the threshold and 0 for the rest. The output data of the analysis are presented as histograms and interpreted.

6. Findings and discussion

The results of the analysis are pointed out in this section. Key findings are depicted and interpreted using histogram and XY plots. While Figure 4 shows the frequency and weight of BIM usage in sustainable construction projects, the impact of BIM on project success is presented in Figure 5. BIM tools are used by 33% of the participants, however, that is not a thoroughly usage. Therefore, their impacts on project success are low.



The results show that permanent project teams have a positive effect on the project success with the exception of one case (Figure 6).

Detailed data analysis and integrated design process are the other important indicators for sustainable construction projects.

Figure 7 shows the mostly positive impact of data analysis in the predesign and design phases of the building production process. Similarly, it can be easily said that there is a direct proportion between integrated design process and project success. The more integrated design process, the more project performance gained (Figure 8).

Fig. 4 The frequency and weight of BIM usage

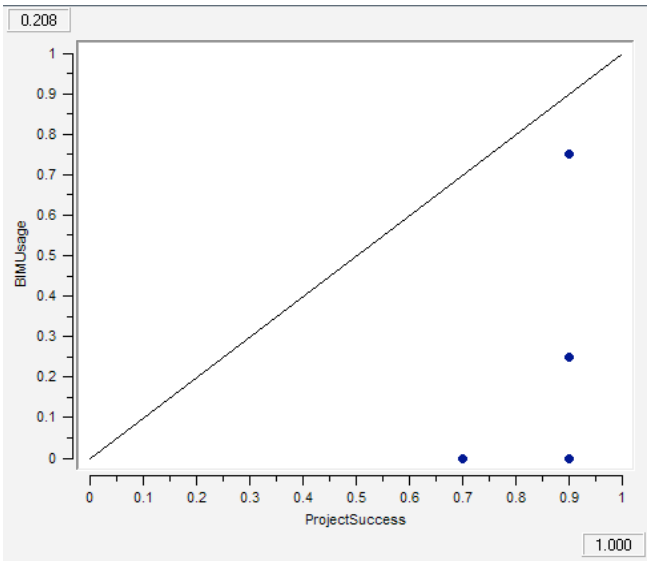


Fig. 5 BIM Usage – Project Success

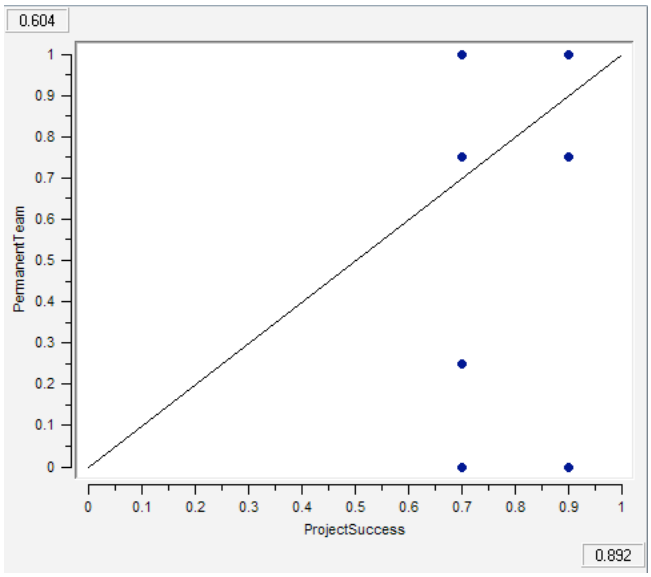


Fig. 6 Permanent Team – Project Success

There is a direct proportion between consultancy services and project success to a large extent as shown in Figure 9. The early participation of green consultants to the design process has a great importance for the success of sustainable projects. On the other hand, Figure 10 compares data analysis and design process. As might be expected there is linearity between the two variables.

It is also necessary to mention about the conceptions of the other topics not listed as conditions in the analysis such as impact on fees and the future of BIM and sustainability. Most participants indicated that they do not charge additional fees due to carrying out sustainable and/or BIM projects. Although the general view of sustainability in Turkish construction industry in the near future is positive, there is a long way to make the sustainable projects by legal regulations and the certificates cease to be an advertising tool.

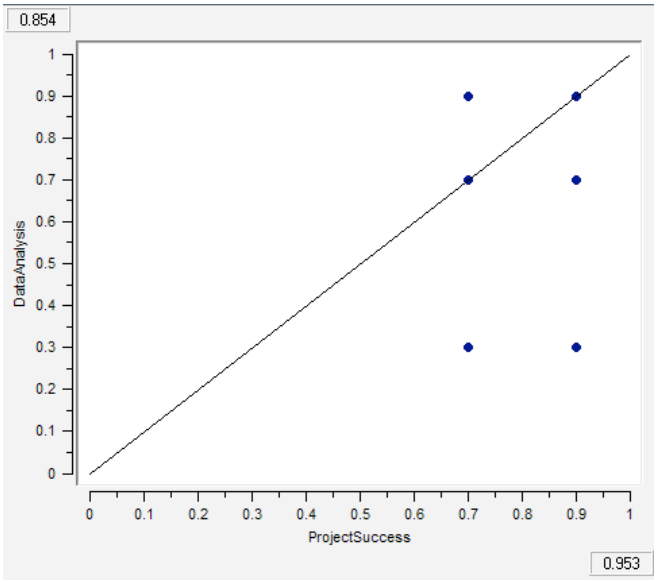


Fig. 7 Detailed Data Analysis – Project Success

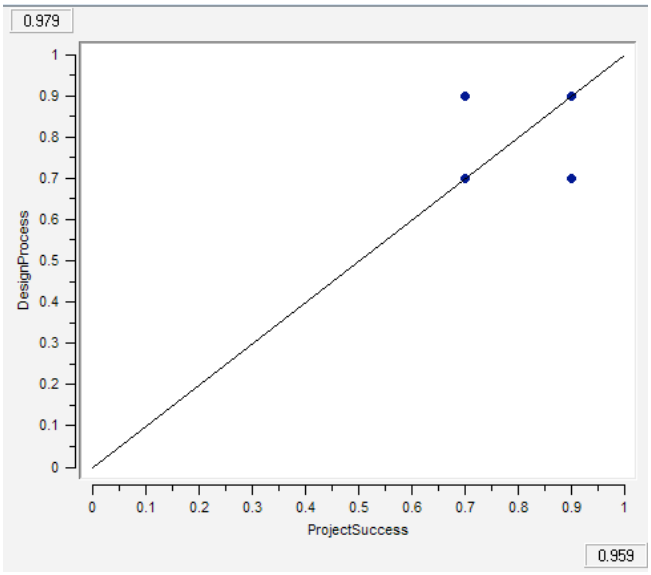


Fig. 8 Integrated Design Process – Project Success

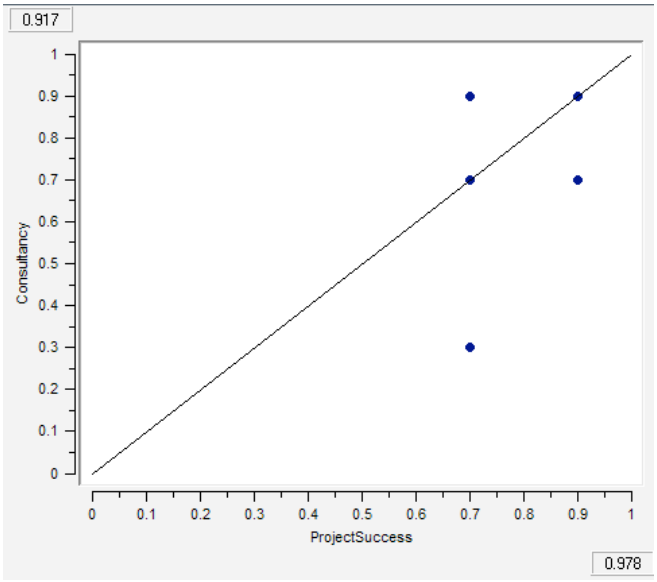


Fig. 9 Consultancy – Project Success

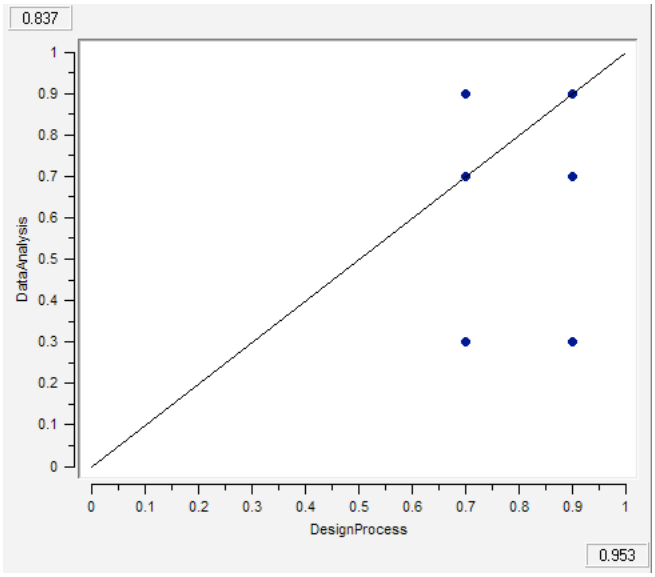


Fig. 10 Detailed Data Analysis – Integrated Design Process

7. Conclusion

The understanding and acceptance of BIM and sustainable construction integration has increased in recent years, however, it is difficult to mention about a perfect incorporation for obvious and accessible solutions. This paper finds out the relationship between BIM and sustainable construction projects as the first step of a functional model for this integration by examining the status of the firms that carry out sustainable projects in Turkey. Other factors such as sustainable data analysis, design process and consultancy services are also analysed via fsQCA besides BIM usage in order to point out their impacts on sustainable projects. The results of the analysis show that BIM is not used thoroughly for sustainable projects including all building production processes due to lack of allocated budget for efficient BIM usage and qualified staff. The benefits provided by BIM software in the design process are not yet realized by the designer, contractor and owners.

On the other hand, detailed data analysis, integrated design process with green consultants and having a permanent project team have great importance on the success of sustainable construction projects. Moreover, the difficulty of developing sustainable material and IFC database and the limitation of using current standards in Turkey can be listed as drawbacks of BIM and sustainability integration. This study is limited due to these factors. However, detailed analyses addressing new variables are needed for future studies. Similarly, the substructure for BIM integration with standards of sustainable construction should be presented at the end of a broader perspective analysis.

8. References

[1] buildingSMART, Model – Industry Foundation Classes (IFC), 2008, The buildingSMART International home of openBIM website, http://buildingsmart.com/standards/ifc, accessed, January 2012.

[2] BREEAM, BRE Environmental Assessment Method website, 2010, http://www.breeam.org, accessed, April 2012.

[3] BSRIA, BREEAM or LEED - strengths and weaknesses of the two main environmental assessment methods, 2009, The built environment experts website, http://www.bsria.co.uk/news/breeam-or-leed/, accessed, June 2012.

[4] EASTMAN, C.M., Building Product Models, 1999, CRC Press, London, Great Britain.

[5] EASTMAN, C. M., TEICHOLZ, P., SACKS, R., and LISTON, K., BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Architects, Engineers, Contractors and Fabricators, 2011, John Wiley and Sons, Hoboken NJ.

[6] HAAGENRUD, S. E., BJØRKHAUG, L., WIX, J., TRINIUS, W., and HUOVILA, P. *"EU-project STAND-INN-Integration of standards for sustainable construction into business processes using BIM/IFC"*, Proceedings of eWork and eBusiness in Architecture, Engineering and Construction, 2009.

[7] KENT, R., Using fsQCA A Brief Guide and Workshop for Fuzzy-Set Qualitative Comparative Analysis, 2008, http://www.ccsr.ac.uk/publications/teaching/2008-10.pdf, accessed, June 2012.

[8] KYMMELL, W., Building Information Modeling, Planning and Managing Construction Projects with 4D CAD and Simulations, 2008, McGraw-Hill, New York, USA.

[9] KRYGIEL, E. and NIES, B. (2008). Green BIM: Successful Sustainable Design with Building Information Modeling. Wiley Publishing, Indianapolis, Indiana.

[10] McGRAW_HILL Construction (2010). SmartMarket Report, Green BIM.

[11] OLSEN, W., Qualitative Comparative Analysis, 2009, http://www.methods.manchester.ac.uk/methods/qca/index.shtml, accessed, June 2012.

[12] RAGIN, C. C., User's Guide to Fuzzy-Set/Qualitative Comparative Analysis 2.0. Tucson, 2006, Arizona: Department of Sociology, University of Arizona.

[13] RAGIN, C. C., DRASS, K. A. and DAVEY, S., Fuzzy-Set/Qualitative Comparative Analysis 2.0. Tucson, 2006, Arizona: Department of Sociology, University of Arizona.

[14] USGBC, 2011, U.S. Green Building Council website. http://www.usgbc.org, accessed, June 2012.

[15] VOZZOLA, M., CANGIALOSI, G. and LO TURCO, M., *"BIM Use in the Construction Process"*, 2009, Management and Service Science. MASS '09 International Conference, 20-22 September, China.

[16] WU, W. and ISSA, R. R. A., "*BIM Facilitated Web Service for LEED Automation. 2011,* ASCE, Computing in Civil Engineering.