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Development of a Roadmap for Assessment the Sustainability of Buildings in Saudi Arabia Using Building Information Modeling

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***Abstract*—**Achieving environmental sustainability is one of the important issues considered in many countries' vision. Green/Sustainable building is widely used terminology for describing a friendly environmental construction. Applying sustainable practices has a significant importance in various fields, including construction field that consumes an enormous amount of resource and causes a considerable amount of waste. The need for sustainability is increased in the regions that suffering from the limitation of natural resource and extreme weather conditions such as Saudi Arabia. Since buildings designs are getting sophisticated, the need for tools, which support decision-making for sustainability issues, is increasing, especially in the design and preconstruction stages. In this context, Building Information Modeling (BIM) can aid in performing complex building performance analyses to ensure an optimized sustainable building design. Accordingly, this paper introduces a roadmap towards developing a systematic approach for presenting the sustainability of buildings using BIM. The approach includes set of main processes including; identifying the sustainability parameters that can be used for sustainability assessment in Saudi Arabia, developing sustainability assessment method that fits the special circumstances in the Kingdom, identifying the sustainability requirements and BIM functions that can be used for satisfying these requirements, and integrating these requirements with identified functions. As a result, the sustainability-BIM approach can be developed which helps designers in assessing the sustainability and exploring different design alternatives at the early stage of the construction project.

***Keywords*—**Green buildings, sustainability, BIM, rating systems, environment, Saudi Arabia.

I. Introduction

SUSTAINABILITY/Green is a broad term describing how to meet the present people requirements without affecting the capability to meet the demands of the future generations. The limited of natural resources and increasing adverse impacts of human activities on the environment enhances the need to implement the sustainability concepts in our life [1]. This need increases in the regions that suffering from harsh environmental conditions and water scarcity such as Saudi Arabia. Among many other fields such as transportation, industry, and agriculture, the construction sector is responsible for a massive amount of waste production and CO_2 emissions [2], [3]. Also, the building construction sector alone consumes about 30% of total produced energy [3]. Therefore, developing sustainable building has grown rapidly as the response of constructions' environmental negative impacts [4]. Sustainability assessment is very important step for developing sustainable buildings. Using BIM in sustainability assessment helps in achieving the evaluation in easier, faster and more accurate manner.

BIM is a widely used terminology that significantly impacts the evolution of the construction industry [5]. BIM is the evolution and use of a computer software model to simulate the construction and operation of a facility [6]. In other words, BIM represents a shift from electronic drafting to a model-based process. The building model resulting from using BIM presents a digital representation of the building's elements and includes an enormous amount of information and properties that can be utilized by various project participants anytime and anywhere according to their needs [7]. This information can be extracted and analyzed to use it for various purposes such as decision making and process improvement. The BIM model can be a 4D model by connecting model elements to time schedules, and it can be a 5D model by integrating cost estimation with model components. This paper introduces a roadmap for developing a systematic approach that combines the BIM functions with the sustainability requirements. The objective of this integration is to assist in evaluating the sustainability and developing a green building. This approach has been designed to satisfy the particular sustainability requirements for the Kingdom of Saudi Arabia.

II. Sustainability in Saudi Arabia

The main motivations for developing sustainable buildings are environmental, energy, water considerations, and some other factors such as health and quality of life factors [8]. This motivation increases in the regions that are suffering from extreme weather conditions such as Saudi Arabia. With no permanent lakes or rivers, Saudi Arabia is considered one of the driest areas in the world, and which depends heavily on water desalination plants to meet the growing needs for fresh water thereby making the country the largest producer of desalinated water in the world [9]. Despite this limitation of water resources, Saudi Arabia is classified as one of the most major water consuming countries in the world. Also, water tariffs in Saudi Arabia are very cheap (approximately

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$0.03/m^3) compared with about $6/m^3 in many of water-rich countries around the world [10]. About the energy issue, Saudi buildings depend heavily on air conditioning that consumes a huge amount of energy needed to generate the electricity [11]. Moreover, the power generation in Saudi Arabia depends mainly on burning fossil fuels which cause a significant impact on air, land, water, and different environment elements [12]. Accordingly, there is a pressing need to implement sustainable practices in Saudi buildings to improve the efficiency of natural resource and to minimize the negative environmental impact [11], [13].

There are many aspects that can affect selecting the criteria of sustainability assessment tools such as economic, social, environmental, and cultural issues. Hence, standard international approaches for evaluating the sustainability of construction projects in all regions, taking into account differences in all of these aspects does not exist yet [14]. Accordingly, each region needs to develop its sustainability assessment method that considers its requirements [15], [16], [14], [17]. Banani et al. [14] highlighted the need to develop sustainability assessment method for Saudi Arabia through investigating and comparing some of the most popular sustainability assessment schemes and highlighting the influence of the different region's aspects on the evaluation criteria and results.

In 2008, BREEAM-Gulf was adapted to match the environment requirements in the Gulf region. However, it is withdrawn in 2010 and cannot be used now [17]. Accordingly, UAE developed their sustainability rating system which called Pearl. In 2009, Saudi Green Building Council (SGBC) had been established to promote the sustainable building knowledge through organizing and participating several national and international conferences, workshops, and other activities. In 2011, Taleb and Sharples evaluated the consumption of water and energy of existing housing in Saudi Arabia with the ultimate aim of introducing guidelines for developing sustainable residential projects in future [18]. In 2013, Alyami et al. [19] exerted some efforts toward identifying the sustainability criteria for residential buildings in Saudi Arabia. They concluded that there is a need for a future works for delivering a weighting system for sustainability criteria and their main groups.

Accordingly, there is an urgency need to develop a unique sustainability assessment method for Saudi Arabia which will be very beneficial to the concerned authorities [17]. Integrating this unique sustainability assessment method with BIM makes the assessment more effectively which helps designers develop sustainable buildings.

III. Sustainability-BIM Systematic Approach

This study highlights the processes toward developing the systematic approach for assessing the green buildings with the help of BIM which called Green-BIM approach. This approach consists of three main processes (shown in Fig. 1), which are; identifying the sustainability parameters, developing national assessment method, and integrating the sustainability requirements with BIM functions. The following subsections discuss these sections in details.

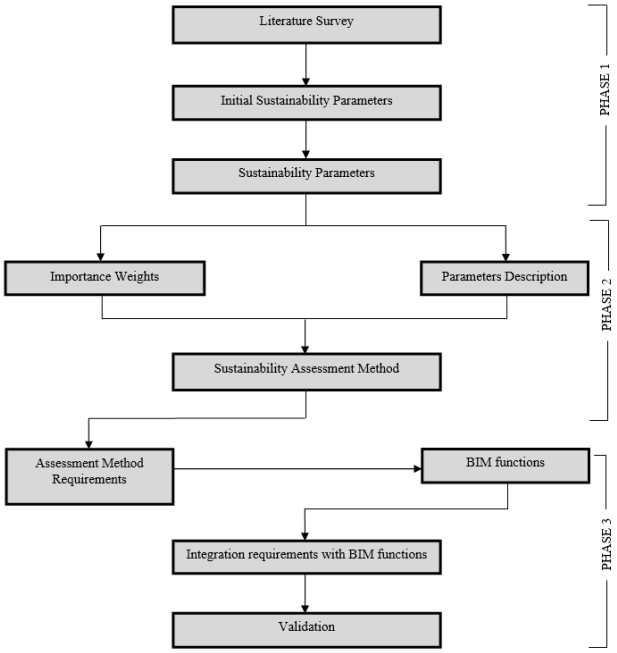

Fig. 1 The main components of Sustainability-BIM approach

A. Identifying the Sustainability Parameters

To achieve sustainable construction, the sustainability measures/parameters should be investigated [20]. These parameters and their importance weights vary from region to region depending on the different of environmental, social and economic conditions [17]. As an example of this variation, Fig. 2 illustrates the main difference between five international and regional sustainability assessment/rating systems, which are; LEED-USA, BREEAM-UK, Green Globes-Canada, GPRS-Egypt, and Pearl-UAE. Furthermore, the sustainability parameters and their weights can be different according to building type. Fig. 3 provides an example of this concept through comparing the sustainability parameters and their weights for three types of structures includes in the LEED rating system. Therefore, many organizations that are interested in sustainability investigated the sustainability parameters and developed sustainability assessment systems based on these measures to evaluate the sustainability of a particular region and also for the specific type of construction. Accordingly, a large number of sustainability assessment systems appeared in many countries in the worlds.

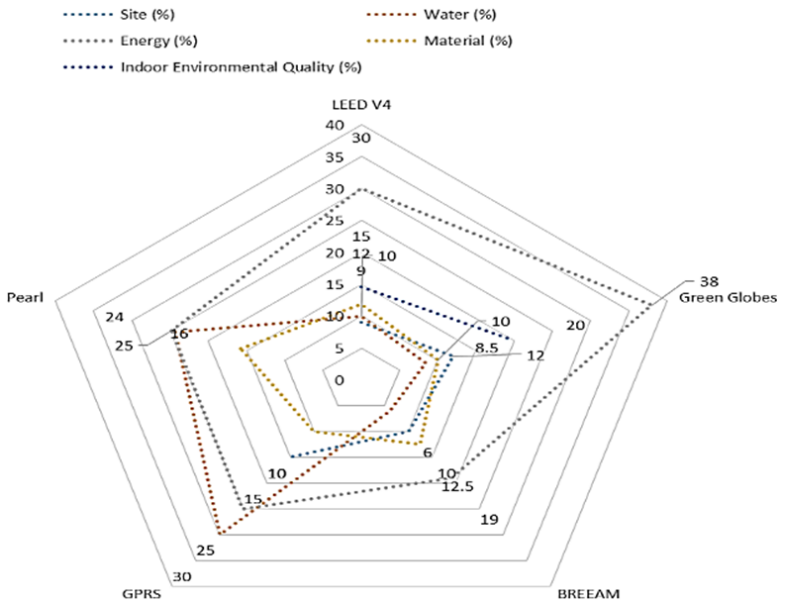

Fig. 2 Comparison between sustainability rating systems

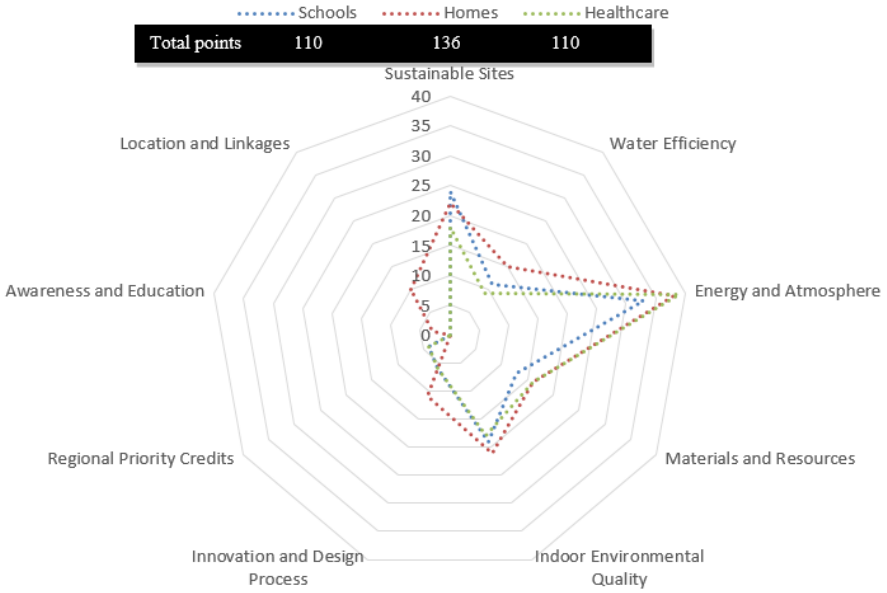

Fig. 3 Comparison between buildings' types

To identify the sustainability parameters appropriate to the sustainability requirements of Saudi Arabia, a set of steps should be achieved, as shown in Fig. 4. The first step highlights the technical information about some international and regional sustainability building assessment systems. Through reviewing a set of local and international sustainability building assessment systems, some international and regional systems can be selected to be the base of selecting the initial sustainability parameters.

The selected sustainability systems should be compared and reviewed in depth. Accordingly, a list of initial parameters can be identified and classified into several groups. A brief description should be added for each criterion to clarify its meaning. The list of initial parameters can be reviewed and modified through a pilot study with some experts to validate this list before launching a questionnaire that includes these parameters. The verified list of initial parameters can be considered as the base of a questionnaire that helps in identifying the sustainability parameters that fits the environmental and social requirements in Saudi Arabia. The principal goal of this survey is to test the appropriateness of the identified initial sustainability parameters to be used for evaluating the sustainability of buildings in Saudi Arabia. Through analyzing the data gathered through a questionnaire,

the most appropriate parameter can be identified.

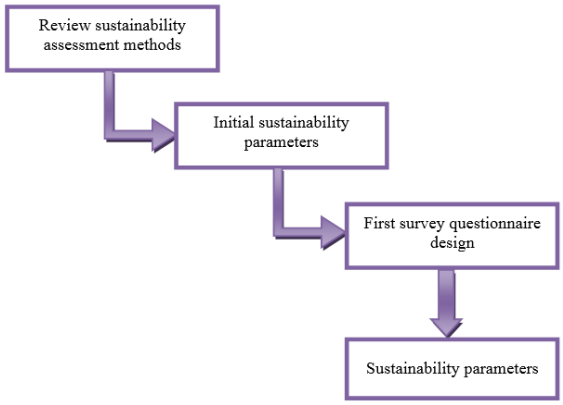

Fig. 4 Investigating the sustainability parameters

B. Sustainability Assessment Method

As a result of the previous phase of the study, a set of sustainability parameters appropriate to be used for evaluating the sustainability of buildings in Saudi Arabia can be identified. This phase aims to identify the importance weight of these criteria to develop the sustainability assessment method. This phase is broken down into the following steps as shown in Fig. 5. The differences in the importance weight for sustainability parameters should be considered during developing the sustainability assessment method. Hence, the first step in this phase aims to identify an appropriate technique for estimating the relative importance weights for sustainability parameters that have been discussed in the previous phase. Of the most popular numerical techniques for estimating the relative importance, weights are Analytical Hierarchy Process (AHP) and Simos procedure. These techniques identify the importance weight for each parameter comparing with other parameters. AHP technique makes a pairwise comparison between each two parameters and develops a matrix based on this comparison. However, developing the comparison matrix becomes tough with a large number of parameters. Thus, this technique usually used with a small number of parameters. Due to the number of sustainability parameters is usually large; Simos technique will be more suitable for estimating the importance weight for these parameters. This technique helps the decision maker to express the hierarchy required for a range of parameters [21], [22]. It depends on arranging a set of cards that include the parameters according to their importance in ascending order from least to most important [23]-[25]. Accordingly, Simos technique can be used in this phase of the study.

The second step of this phase of study includes developing a second survey questionnaire that considers the Simos technique requirements. This questionnaire will help in gathering data from experts to identify the importance weight for sustainability parameters. Through analyzing the data collected via Simos procedures, the relative importance weights for each parameter can be identified. Another statistical technique can be used to identify the key sustainability parameters based on their weights and ignoring the trivial parameters. Based on previous steps, a sustainability assessment method can be developed which includes; the key sustainability parameters, relative importance weights, and parameters description. The proposed method can be used for assessing and rating the sustainability of buildings and selecting the best design alternatives.

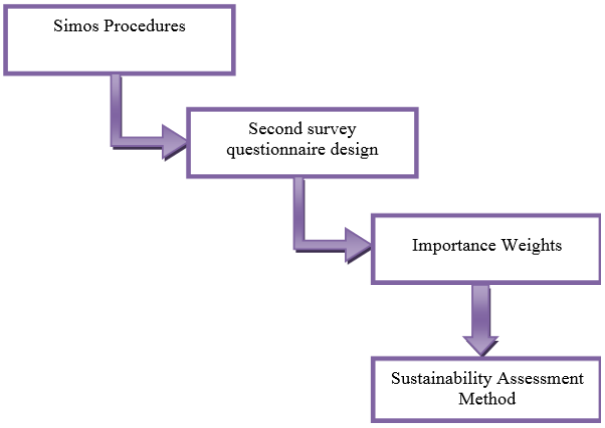

Fig. 5 Developing sustainability assessment method

C. Integrating the Sustainability Requirements with BIM Functions

This phase of the study uses the results of previous phases to develop the sustainability assessment approach that uses BIM functions. In other words, this stage is answering the question of how the sustainability parameters can be estimated through BIM functions. This phase is broken down into several steps shown in Fig. 6. The first step of this phase of the study aims to identify the measurement requirements for each of the sustainability parameters and classify them according to the data requests type. This step helps in identifying the estimation plan for each sustainability parameter. In the second step, the BIM functions that can contribute to satisfying the sustainability requirement should be investigated. These functions are available in many BIM applications such as Autodesk Revit, Ecotect, Tekla structure, and Energy Plus. Available BIM functions can be extended using Revit API (Application Programming Interface). Revit API provides a very helpful tool for inserting external applications into Revit products such as sending data to other applications or linking with external database [26], [27]. Many programming languages are compatible with Revit API such as C#, C++, and Visual Basic. The third step of this phase of study aims to match up the data required for sustainability parameters with the BIM functions that identified in previous steps. This integration helps in determining how to calculate each of sustainability criteria requirements through BIM functionalities. Fig. 7 shows the workflow for sustainability assessment via BIM. The sustainability parameter should be included in BIM model via API. Then through identifying the requirements for this parameter and the BIM function that can be used for satisfying the identified requirements, the data required for measuring the sustainability parameter can be

extracted from BIM model.

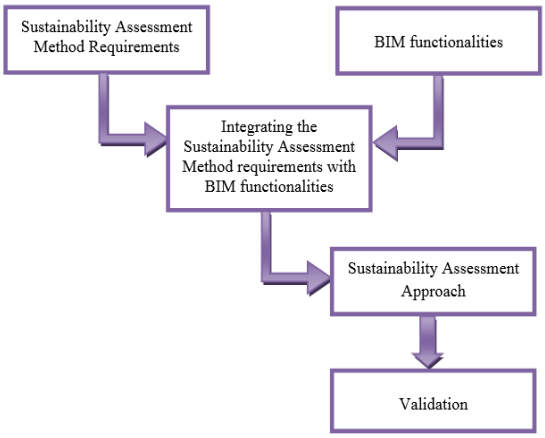

Fig. 6 Integrating the sustainability assessment method requirements with BIM functions

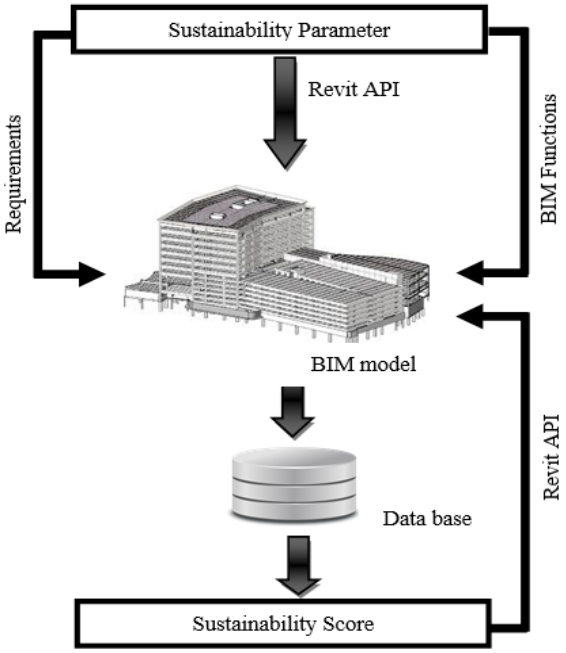

Fig. 7 The workflow for sustainability assessment via BIM

These data can be stored in the external database. Accordingly, the sustainability score for this parameter can be calculated based on the data stored in the database. The calculation results can also be linked with BIM through API. The output of this phase considers as an approach for evaluating the sustainability using BIM. The applicability of this approach needs to be validated through integrating some selective quantitative criteria with the BIM for a case study. The proposed approach can be modified and improved according to the validation results.

IV. Conclusion

The construction sector has a significant impact on the environment and also consumes a considerable amount of natural resources, and thus, there is growing interest in developing green/sustainable buildings. The environmental conditions and regional requirements usually vary from one country to another. Accordingly, each country needs to develop a sustainability assessment method that meets their requirements. This need increases in countries that are suffering from harsh weather conditions such as the Kingdom of Saudi Arabia. This study highlights the main processes of for developing a systematic approach that helps in achieving sustainable buildings in Saudi Arabia using BIM. This approach consists of four main components which are; sustainability parameters, sustainability assessment method, sustainability requirements, and BIM functions. The proposed approach introduces fast, accurate, and more efficient manner for sustainability evaluation. Accordingly, using this approach helps designers in evaluating and comparing different design scenarios and selecting the most sustainable design alternative. It is highly recommended to enact some legislation and motivations to encourage implementing green buildings in Saudi Arabia.

References

[1] Ljungberg, Lennart Y. "Materials selection and design for development of sustainable products." Materials & Design 28, no. 2, 2007, pp 466-479.
[2] Bakhoum, Emad S., and David C. Brown. "Developed sustainable scoring system for structural materials evaluation." Journal of construction engineering and management 138, no. 1, 2011, pp 110-119.
[3] IPCC. "IPCC WG1 Fourth Assessment Report." Cambridge University Press: New York, 2007, Retrieved from http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf.
[4] Hoffman, Andrew J., and Rebecca Henn. "Overcoming the social and psychological barriers to green building." Organization & Environment 21, no. 4, 2008, pp. 390-419.
[5] Rogers, John Peter. "The strategic adoption of building information modelling by Malaysian engineering consulting services firms." 2013.
[6] AGC. "The Contractors' Guide to BIM.Ed. 1." The Associated General Contractors of America, 2006, retrieved from http://www.agc.org/and workflows, Wiley, Indianapolis, IN.
[7] Azhar, Salman, Malik Khalfan, and Tayyab Maqsood. "Building information modelling (BIM): now and beyond." Construction Economics and Building 12, no. 4, 2015, pp.15-28.
[8] Edwards, Brian. Rough guide to sustainability. London: RIBA Enterprises Ltd., 2010.
[9] Vincent, Peter. Saudi Arabia: an environmental overview. CRC Press, 2008.
[10] Gasson, Christopher. "Tariff policy: a global perspective." In Saudi water and power forum, Jeddah. 2008.
[11] Taleb, Hanan M. "Towards Sustainable Residential Buildings in the Kingdom of Saudi Arabia." PhD diss., University of Sheffield, School of Architecture, 2012.
[12] Alnatheer, Othman. "Environmental benefits of energy efficiency and renewable energy in Saudi Arabia's electric sector." Energy Policy 34, no. 1, 2006, pp. 2-10.
[13] Alrashed, Farajallah, and Muhammad Asif. "Saudi building industry's views on sustainability in buildings: questionnaire survey." Energy Procedia 62, 2014, pp. 382-390.
[14] Banani, R., Maria Vahdati, and A. Elmualim. "Demonstrating the importance of criteria and sub-criteria in building assessment methods." PhD diss., WIT Press, 2013.
[15] Reed, R., Bilos, A., Wilkinson, S., & Schulte, K. W. "International comparison of sustainable rating tools." Journal of sustainable real estate, 1(1), 2009, pp. 1-22.
[16] Larsson, N. User Guide to the SBTool assessment framework. iiSBE, 2012,October 24.
[17] Shaawat, M. Essam, and Rehan Jamil. "A Guide to Environmental

Building Rating System for Construction of New Buildings in Saudi Arabia." Emirates Journal for Engineering Research 19, no. 2, 2014, pp. 47-56.
[18] Taleb, Hanan M., and Steve Sharples. "Developing sustainable residential buildings in Saudi Arabia: A case study." Applied Energy 88, no. 1, 2011, pp. 383-391.
[19] Alyami, Saleh H., Yacine Rezgui, and Alan Kwan. "Developing sustainable building assessment scheme for Saudi Arabia: Delphi consultation approach." Renewable and Sustainable Energy Reviews 27, 2013, pp.43-54.
[20] Abdallah, Moatassem, Khaled El-Rayes, and Liang Liu. "Operational performance of sustainable measures in public buildings." Journal of construction engineering and management 139, no. 12, 2013, A4013008.
[21] Simos, J., "evaluation environmental: Un processus cognitif negocie. These de doctorat, DGF-EPFL, Lausanne, 1990a.
[22] Simos J. "Evaluer l'impact sur l'environnement: Une approche originale par l'analyse multicritère et la négociation," Presses Polytechniques et Universitaires Romandes, Lausanne, 1990b
[23] Roy, B., Bouyssou, D. "Aide multicrit_ere _a la d_ecision: M_ethodes et case, Economica." Collection Gestion, Paris, 1993.
[24] Roy, B., Mousseau, V. "A theoretical framework for analysing the notion of the relative importance of criteria." Journal of Multi-Criteria Decision Analysis 5, 1996, pp.145–149.
[25] Shanian, A., Abbas S. Milani, Natasha Vermaak, Katia Bertoldi, Tom Scarinci, and Miklos Gerendas. "A combined finite element-multiple criteria optimization approach for materials selection of gas turbine components." Journal of Applied Mechanics 79, no. 6, 2012, 061019.
[26] Autodesk. "Revit 2010 API: Developer's Guide, Version 1.0." Autodesk,2009,http://usa.autodesk.com/adsk/servlet/index?siteID=123112andid=2484975.
[27] Wu, Wei. Integrating building information modeling and green building certification: The BIM-LEED application model development. University of Florida, 2010.