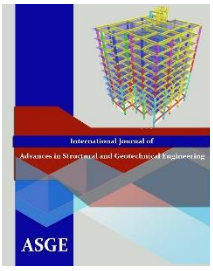

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AN AUTOMATED BIM-EMBEDDED APPROACH FOR RULE BASED CHECKING FOR GREEN BUILDING DESIGN IN EGYPT

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ABSTRACT

Assuring the quality of the building design is one of the most vital issues while compiling a construction project especially amid the urgent actions towards affecting climate change risks and attempts to achieve Sustainable Development (SD) goals. Recently, Egypt has experienced deficit in electricity due to high demand and consumption of electricity in different building sectors. Therefore, ensuring sustainable and energy efficient buildings can assist in reducing energy demand and saving energy. TARSHEED, as a non-governmental measure to develop a local green building rating system. Building Information Modelling (BIM) as an efficient tool that is recently used to facilitate the design process and increase accuracy and interoperability as well as assisting local governments to ensure assigned standards of quality in building design specially safety and energy efficiency. With the help of BIM, previous successful measures and attempts were conducted to automate rule-based checking. This research investigates a BIM-based approach for automating checking of TARSHEED rating system. The developed approach utilizes as much information available in a building's BIM model as possible to automate the design evaluation complied with TARSHEED criteria.

Keywords: TARSHEED, BIM, Automation, LEED, rule-based checking, green building, rating systems.

INTRODUCTION

A major increase in energy consumption is expected for the upcoming few years with a rate of growth of 6.8 percent. The primary energy supply in Egypt increased from 67.2 million tons of oil equivalent (M.toe) in 2007 to 89.2 M.toe in 2012 [1]. Multiple ministerial decisions have been issued for Egyptian to work for the Egyptian code for improving energy efficiency in buildings [2].Those decisions are indicated as the following:

- Ministerial decision 2005/482, Works for Egyptian code for enhancing energy efficiency use for residential building.
- ministerial decision 2009/190 Works for Egyptian code for enhancing energy efficiency use for commercial building.
- ministerial decision 2010/433, Works for Egyptian code for enhancing energy efficiency use for governmental building.

In August 2009, the Egyptian Supreme Council of Energy have established an Energy Efficiency Unit under the umbrella of the Ministry Cabinet to set a plan to reduce the energy consumption by 5% in 2010 relative to year 2009 [3]. In addition, a New Supreme Council of Green Buildings was also established in 2009 to propose a New local Green Building Code for Newly built Urban Communities. The upgraded version of the Green Pyramid Rating System (GPRS) has been recently developed[4].

However, there is no registered buildings for GPRS certification, even governmental buildings. GPRS is still not applied in the Egyptian construction market which may be a sign for rethinking the obstacles of its application [5]. The residential buildings consume about 41.1 percent of the total energy consumption, commercial buildings take 8.2 percent of the total energy consumption and Governmental buildings consume 4.9 percent. The total number of residential units in Egypt is over than 20 million unit while mixed-use units are approximately 6 million units. The residential building sector demand is approximately 51 TWh electricity and 7 Mtoe energy [6]. Accordingly, an incentive by Egyptian professionals that work in the field of sustainability and environmental design, have collaborated and created TARSHEED rating system for residential buildings.

TARSHEED is a recently developed local building rating system by Egypt Green Building Council (EGGBC), a member of the World Green building council [7]. TARSHEED is an Arabic word that means rationalization. It is considered as a recent measure to promoting green buildings in Egypt besides raising public awareness about sustainability by a non-governmental organization. It is developed after examining the experiences of many GBCs around the world and studying different Green Building Rating Systems applied globally and in the MENA Region namely: LEED, BREAAM, ESTIDAMA, GSAS and EDGE [8]. TARSHEED rating system is mainly customized for the Egyptian environment. TARSHEED certified buildings are supposed to achieve a minimum of 20% reduction in energy, water, and habitat [9]. It has four levels of certification; bronze, silver, gold and platinum. TARSHEED also works for both new communities and existing communities. Rashed and Ismaeel [5] has conducted a study comparing among LEED, GPRS and TARSHEED rating system based on the adopted criteria and environmental assessment. TARSHEED gives the most attention to energy efficiency and habitat. Meanwhile, it is not giving much attention to other factors of environmental assessment. Accordingly, they recommended multiple plans to develop the mentioned rating systems.

One of the most important advantages of Building information modelling (BIM) is interoperability which means “the ability to share the data between different stakeholders during all stages of a project from predesign to occupancy”[10]. There are multiple BIM products available commercially. Autodesk Revit Architecture is the most common application and widely used among stakeholders in design and construction projects. It enables use of parametric modeling with both graphical and non- graphical information. It also allows to integrate external applications via Revit Platform Application Programming Interface (API). It enables to develop add ins or plugins that can facilitate specific functions done by Revit. So that it enables applying external features to a BIM model [10]. In recent five years, BIM as tool of facilitating the design process and increasing the quality and accuracy in the project design; is receiving wide acceptance in the construction market and enlarging application in many projects in Egypt. In order to develop rule-based compliance checking system to be more reliable without having human errors in revising and assuring the quality of design; it is vital to integrate TARSHEED rating system Automation within the BIM process by developing a robust model.

LITERATURE REVIEW

There are multiple measures during the last decade who studied the automation of green building rating system process. LEED, as the most previous measures of LEED automation might be divided into three main streams; automated online LEED project management, automated LEED-BIM integration and LEED integrated life-cycle cost. The first stream is mainly meant to facilitate and manage the exhaustive documentation process of LEED. It has been converted into commercial cloud based applications such as GreenGrade [11], IES Tap and Lorax Pro . The second stream is meant to integrate the technology of BIM into the possibility of specific LEED credits achievement. The last stream is concerned with the building life-cycle assessment and its cost. Khan et al. have conducted an automated system called MyCrest-LCC tool that may assist in decreasing construction planning timeline duration and cost. It also can provide better decision making and strategic planning. The research will develop new trend and technique of automation in green building technology in compliance with life cycle cost analysis. This automated MyCrest-

LCC tool will also help investors in their decision making to calculate their initial and future costs in a systematic automation [12]. Han et al. have proposed green building design support system that assist in calculating the acquired points of LEED credits using BIM authoring software and proposes practical revision guidance [13]. Nguyen et al. have developed a plugin on Autodesk Revit that can evaluate the expected LEED score of the new design. In general, the LEED requirements have been converted in to parameters within the BIM model. These LEED parameters can be extracted in order to calculate the maximum possible points for LEED ratings by specific algorithms developed using Revit API [10]. Zhang and Chen have proposed a rule-based tool that can automate the process of lifecycle evaluation of building sustainability. The tool is meant to provide alternatives to get higher LEED grade. It can also monitor the as-built building and evaluate the construction processes [14].

Jalaei and Jrade have proposed semi-automated system that integrates BIM and LCA tools with a database for sustainable building projects. The model incorporates a database of green materials stored and linked to a BIM (3D) module along with a LCA tool. It provides results of expected certification level and cost estimation [15]. Chen and Hsieh have developed a BIM Rule-based model that can assist in the automation of the design evaluation process complied with green building standards. It is supposed to give illustrated real time feedbacks through the BIM model. Moreover, visualization of the green building rule-checking results is supported in virtual reality environment of a building's BIM model [16]. Wu and Issa have presented the new paradigm of delivering LEED projects via LEED Automation facilitated by cloud deployed BIM applications [17]. They have proposed a third-party web service based on BIM that can assist in facilitating LEED documentation process and management [18].they also have discussed the feasibility of integrating Virtual Design and Construction (VDC) into LEED delivery projects with the help of BIM [19].

PROPOSED METHOD

This work aims at identifying the required information for TARSHEED green building evaluation and developing an automated tool for assessment. First, the TARSAHEED points of criteria need to be embedded within the BIM model. They are indicated to be green building indicators and can be created and stored as parameters in the used BIM application. For example, in Revit Architecture, the green building indicators can be created as new project parameters or shared parameters, in which only the shared parameters can be exported to databases as shown in Fig.1. The BIM model in Revit Architecture uses elements such as the components of a building, including site, architectural elements (exterior/interior walls, roof, doors, etc.), structural elements (foundation, column, beam, etc.), and Mechanical systems as shown in Fig. 2

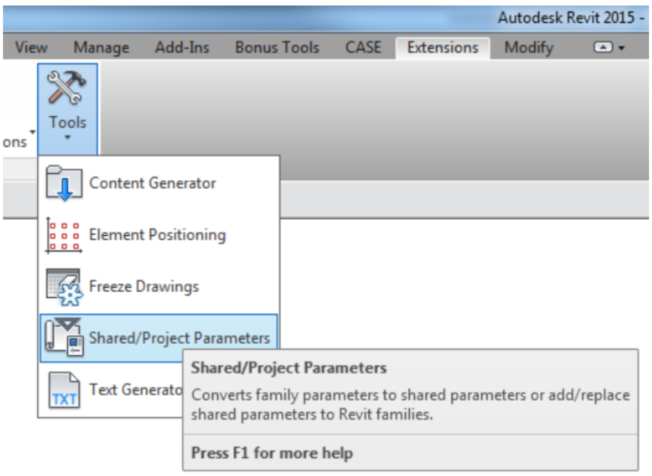


Fig. 1: Shared Parameters in Autodesk Revit

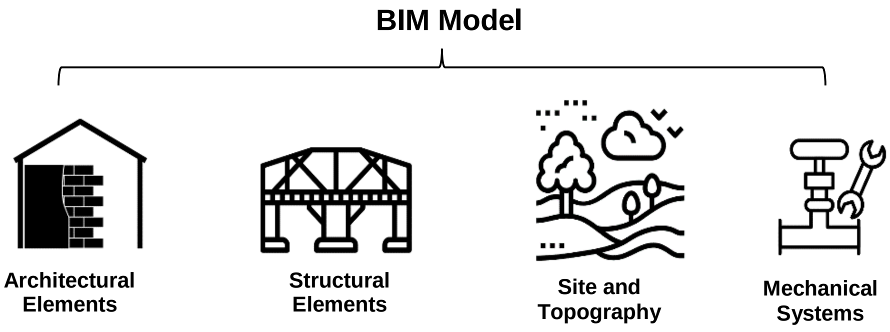


Fig. 2: BIM Model Components

A preliminary framework representing the knowledge contained in the TARSHEED criteria, which is modeled and stored in a BIM model. It was mentioned by [10] that model data can be categorized in to two categories; quantitative and qualitative. The quantitative data can be extracted easily from BIM model. For instance, the orientation of the building, insulation of exterior walls, the window-wall ration, reflectivity of the roof and type of glazing (see Fig.3). This data can be extracted via specific developed algorithms using Revit API and C Sharp programming language. As for the qualitative data that cannot be extracted directly from the BIM model. It needs to be filled by the architect during the design phase. For example, are regional materials used? Is there a construction waste management plan? Fig.4 illustrates the TARSHEED parameters integrated into the BIM model.

Such algorithms/functions can be developed through two main stages;
Stage one: converting the knowledge contained in TARSHEED green building rating criteria into simple human logic sentences.

Stage two: translating such sentences into interned actual codes are developed and implemented.

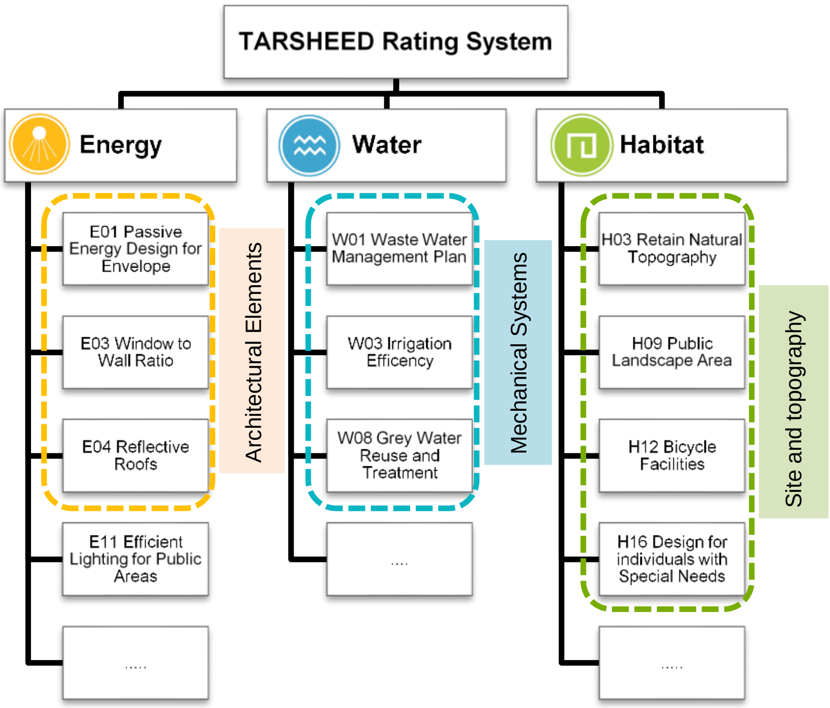


Fig. 3: Proposed Knowledge Representation Framework

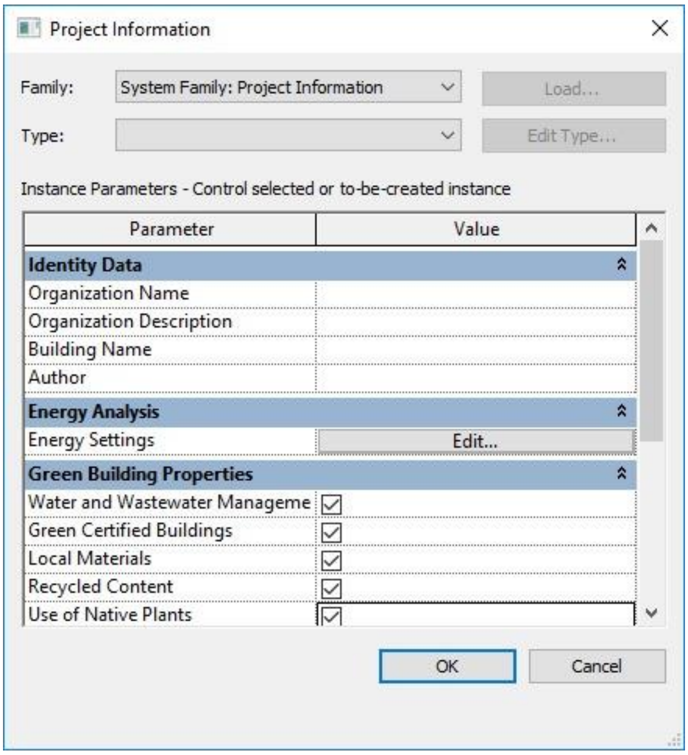


Fig. 4: TARSHEED new project parameters created in the BIM model

Evaluation Functions

In order to evaluate the validity of the represented automation framework for TARSHEED rating system assessment, a proposed functional code for evaluation of the green building score of the TARSHEED category, Energy, was developed and implemented in *Autodesk Revit 2019.* The assessment functional code extracts the needed information from the BIM model of the project and check the compliance with the assigned TARSHEED credit to sum the expected green building score. The required information for assessing the application of a green building credit may vary from building geometry to other data related TARSHEED requirements. As previously mentioned, in many cases, the BIM model does not contain all the needed data for TARSHEED assessment. In such cases, new shared parameters need to be entered manually into the BIM model by the stakeholders themselves in order to facilitate the process of data extraction for TARSHEED automation assessment.

For each category of TARSHEED rating system, the proposed assessment tool checks the compliance with the assigned prerequisites. If the BIM model is complied with the TARSHEED prerequisites, then the proposed tool continues to check compliance with other TARSHEED credits. For each TARSHEED credit category whose requirement is satisfied, the assigned points for credit application are rewarded to the BIM model. The same process is repeated for each credit in the three categories of TARSHEED rating system and the sum of the total TARSHEED score is calculated as an output.

The indicated below is an example describing how the required data for TARSHEED rating system assessment is extracted from the available data of the BIM model. This proposed assessment functional code is for the Energy category. Credit E03 *Window to Wall Ratio*. It has been assumed that a BIM model for a residential building design has been created in Autodesk Revit Architecture with all the required building information for TARSHEED evaluation. Also, the new project information for TARSHEED evaluation is entered in the BIM model as new parameters. Fig. 5 indicates the knowledge contained in credit E03 in TARESHEED criteria and Fig. 6 illustrates a flowchart after converting the credit E03 into human logic sentence.

E03 Window to Wall Ratio

Intent
"To reduce heat loads on the building by reducing heat transfer from windows. To reduce the environmental and economic harms of excessive energy use by improving energy efficiency for the building and its systems".

Base Case
Window to wall ratio is more than 30%

Improvement
"Reduce the WWR to 30% or less. Calculate the "Glazing Area", and the "Gross Exterior Wall Area" for each façade of the building. WWR is calculated using equation (1)"

$$\text{WWR }(\%) = \frac{\Sigma\, Glazing\ Area\ (m2)}{\Sigma\, Glazing\ exterior\ wall\ area\ (m2)} \quad (1)$$

Credit Criteria

E03	Window to Wall Ratio	New Community	Existing Community
	WWR ≤ 30 %	1 point	1 point

Documentation
"Documentation of all window to wall ratio calculations".

Fig. 5: TARSHEED Criteria Credit E03

Output:

TARSHEED score (E03) with respect to the green building credit category ENERGY, Credit E03—Window to Wall Ratio. Fig. 7 represents the developed code for the credit E03 of TARSHEED.

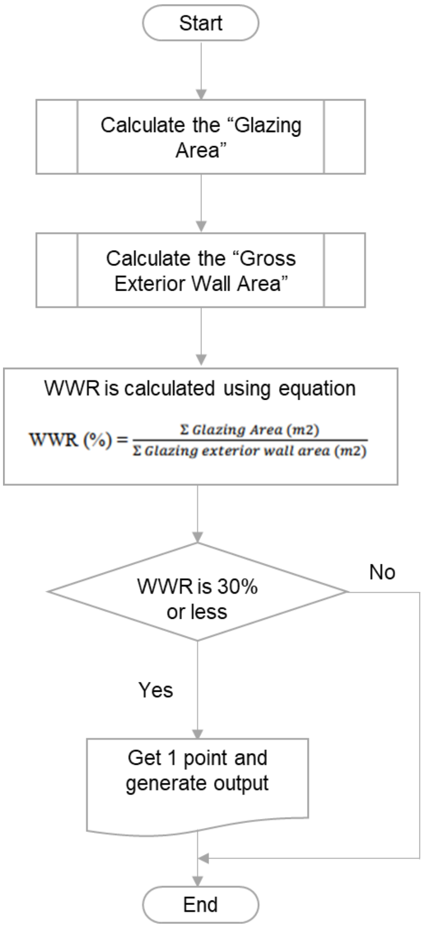


Fig. 6: TARSHEED credit E03 flowchart (Stage One)

```
List<double> Ratios = new List<double>();
foreach (Wall w in walls)
{
    Curve WallCurve = ((LocationCurve)w.Location).Curve;
    double wallheight = w.get_Parameter(BuiltInParameter.WALL_USER_HEIGHT_PARAM).AsDouble();
    double wallArea = WallCurve.Length * wallheight;
    double wallAreaNet = w.get_Parameter(BuiltInParameter.HOST_AREA_COMPUTED).AsDouble();
    double Ratio = (1 - (wallAreaNet / wallArea));
    Ratios.Add(Ratio);
}
double RatioMean = Ratios.Average();

int Points = 0;
if (RatioMean <= 30)
{
    Accepted = true;
    Points += 1;
}
```

Fig. 7: TARSHEED credit E03 assessment code (Stage Two)

Tool Application

The developed automation tool was applied into Autodesk Revit 2019 in order to create a TARSHEED rating system evaluation system. To make the proposed tool work properly, the project BIM Model has been created with Autodesk Revit 2019. All the required data has been added through project shared parameters. For data extraction, a functional code was created using Microsoft.NET using C sharp programming language to ease the process of extraction of the needed information for TARSHEED evaluation. The functional code can be executed through API. After the data extraction, the automation tool checks the compliance of the extracted data with the TARSHEED credit criteria in order to calculate the TARSHEED score and the expected rating level. The TARSHEED score report are supposed to be generated through Microsoft.NET platform using C sharp programming language. Also, the user interface of the TARSHEED automation tool has been developed via Microsoft.NET using C sharp programming language. The TARSHEED automation tool has also the ability to generate Microsoft excel to fill in the TARSHEED score checklist. In order to test the developed TARSHEED automation tool, a BIM model was built in Autodesk Revit Architecture 2019. All the required data for TARSHEED assessment has been completely entered. Fig. 8 illustrates a 3D view of the BIM model.

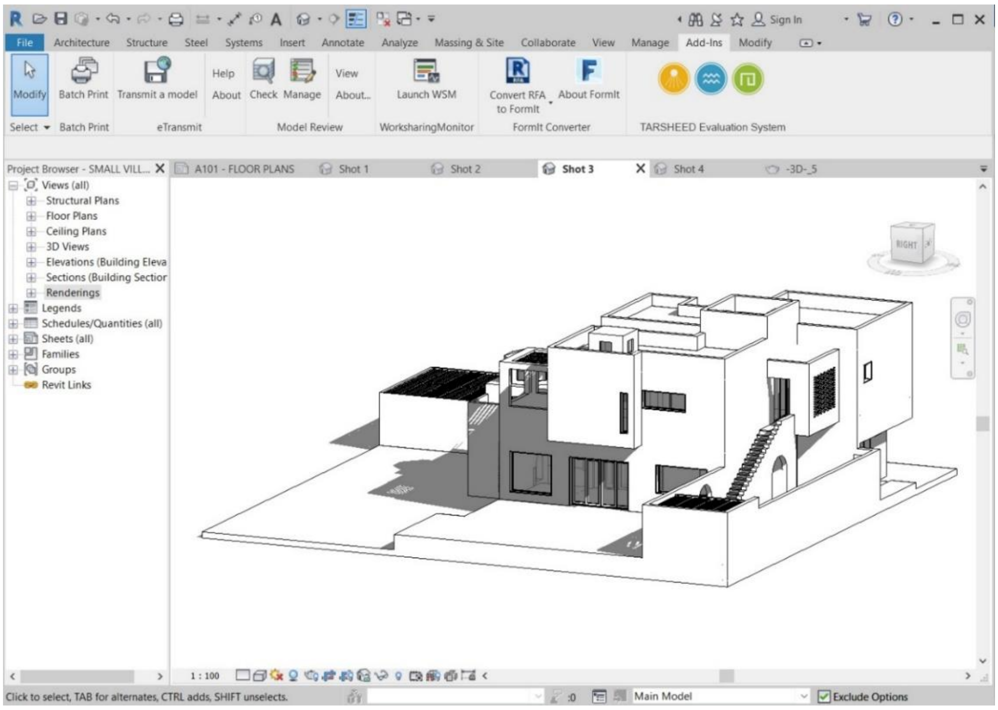


Fig. 8: BIM Model used for testing TARSHEED Automation Tool

The TARSHEED evaluation system icon appears in the add-ins tab in Autodesk Revit. Once the user press on the icon, another user interface window appears as shown in Fig.9. The user is supposed to press on the button of (Import extracted data from BIM model). All the required information will be extracted. There are also load documents buttons that the user can upload the needed document for each category credit. The button Calculate TARSHEED Score is supposed to provide a cumulative score based on the assessment variables within the TARSHEED evaluation system as indicated in Fig. 10.

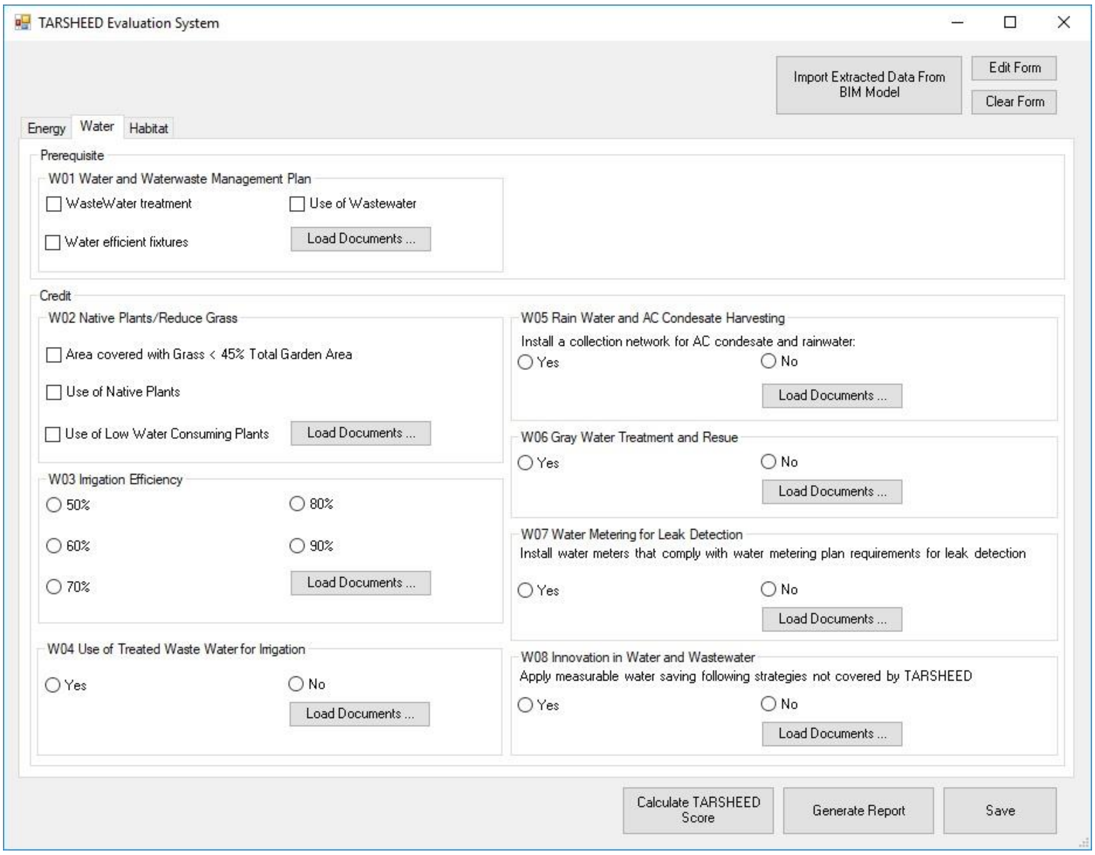
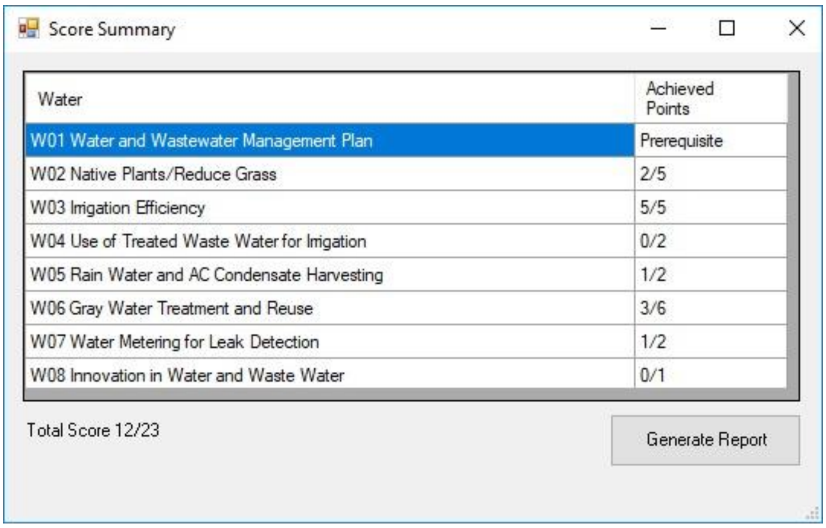


Fig. 9: User Interface of TARSHEED evaluation system



Water	Achieved Points
W01 Water and Wastewater Management Plan	Prerequisite
W02 Native Plants/Reduce Grass	2/5
W03 Irrigation Efficiency	5/5
W04 Use of Treated Waste Water for Irrigation	0/2
W05 Rain Water and AC Condensate Harvesting	1/2
W06 Gray Water Treatment and Reuse	3/6
W07 Water Metering for Leak Detection	1/2
W08 Innovation in Water and Waste Water	0/1

Fig. 10: Assessment summary created by TARSHEED evaluation system

The TARSHEED assessment checklist can be filled and generated via pressing the button of generate report. Fig. 11 illustrates TARSHEED assessment checklist generated by TARSHEED evaluation system.

Tarsheed Communities
Project Checklist

Yes	?	No			
			Credit	Green Building Accredited Professional	1
0	**0**	**0**		**Energy**	**21**
Y			Prereq	E01 Passive Energy Design for Envelope	Prerequisite
Y			Prereq	E02 Commissioning	Prerequisite
			Credit	E03 Window to Wall Ratio	1
			Credit	E04 Reflective Roofs	1
			Credit	E05 Reflective Paint for External Walls	1
			Credit	E06 External Shading Devices	1
			Credit	E07 Roof Insulation	1
			Credit	E08 External Wall Insulation	1
			Credit	E09 High Performance Glazing for Windows	1
			Credit	E10 Air Tightness	1
			Credit	E11 Efficient Lighting for Public Areas	2
			Credit	E12 Light Pollution Prevention	2
			Credit	E13 Photovoltaic Systems for Exterior Lighting	2
			Credit	E14 Solar Water Heaters	2
1			Credit	E15 Pump Motor Efficiency	1
1			Credit	E16 Energy Metering	1
			Credit	E17 On-Site Renewable Energy	3
			Credit	E18 District Heating and Cooling Plant	n/a
0	**0**	**0**		**Water**	**23**
Y			Prereq	W01 Water and Wastewater Management Plan	Prerequisite
			Credit	W02 Native Plants/Reduce Grass	5
			Credit	W03 Irrigation Efficiency	5
			Credit	W04 Use of Treated Waste Water for Irrigation	2
			Credit	W05 Rain Water and AC Condensate Harvesting	2
			Credit	W06 Gray Water Treatment and Reuse	6
1			Credit	W07 Water Metering for Leak Detection	2
			Credit	W08 Innovation in Water and Waste Water	1
0	**0**	**0**		**Habitat**	**55**
Y			Prereq	H01 Construction Activity Pollution Prevention – Dust Control	Prerequisite
Y			Prereq	H02 Solid Waste Management Plan	Prerequisite
Y			Prereq	H03 Green Certified Buildings	Prerequisite
			Credit	H04 Retain Natural Topography	n/a
			Credit	H05 Protect and/or Restore Existing Trees & Water Bodies	na
			Credit	H06 Heat Island Reduction: Reflective Tiles for Outdoor Paving	3
			Credit	H07 Heat Island Reduction: Shaded Parking and/or Underground Parking	3
			Credit	H08 Basic Amenities	4
			Credit	H09 Public Landscape Areas	3
			Credit	H10 Recreation Facilities	3
			Credit	H11 Walkable Streets - Tree-Lined and Shaded	5
1			Credit	H12 Bicycle Facilities	3
			Credit	H13 Internal Transportation Facilities	3
			Credit	H14 External Transportation Facilities	3
			Credit	H15 Organic Fruit and Vegetable Gardens	1
			Credit	H16 Design for Individuals with Special Needs	1
			Credit	H17 Construction Waste Management	3
			Credit	H18 Municipal Waste Management	4
			Credit	H19 Organic Waste Management: Composting	6
			Credit	H20 Local Materials	na
			Credit	H21 Recycled Content	na
			Credit	H22 Green Certified Buildings	6
			Credit	H23 Sustainable Building Guidelines	na
			Credit	H24 Green Education & Community Involvement	4
7	**0**	**0**		**Project Totals (For Certification)**	**100**

Bronze: 40-49 points, **Silver:** 50-59 points, **Gold:** 60-69 points, **Platinum:** 70+ points

Fig. 11: TARSHEED assessment checklist generated by TARSHEED evaluation system

RESULTS AND DISCUSSION

The automation of checking complying with TARSHEED rating system could be achieved through a simple methodology based on two main steps; the first one is creating the design with a BIM model with all the needed data for TARSHEED rating system in the project/shared parameters. the second step is using the add-in feature in the Revit software that automate the whole process of checking compliance with the TARSHEED criteria and generates the final TARSHEED report. Building information modeling has assured a good potential for facilitating the whole process of checking compliance with TARSHEED rating system or any other green building rating system based on the criteria that is created using the functional code that can be executed via Revit API. The proposed automated tool can increase reliability of design assessment and quality check results rather than compliance checking process that is performed manually based on two dimensional drawings. The automation tool is also supposed to decrease the possibility of ambiguity, inconsistency in assessment. It may also assist in eliminating the barriers to green buildings in the Egyptian construction market.

CONCLUSION

Within the recent years, most of architectural designs need to comply with sustainability rating systems or other building regulations due to deficit in electricity, high demand and consumption of electricity. These rating systems are crucial in examining the performance of a building to comply with assigned criteria and regulations. Through the assistance of BIM, the architectural design can not only be inter-operated among project stakeholders but can also be a way to check compatibility with specific building rating system or regulations. This work has focused on proposing an automation tool for compliance checking with TARSHEED rating system which is considered a recent non-governmental measure to develop a local green building rating system for residential buildings in Egypt. The automation tool has been developed using Autodesk Revit API and Microsoft .NET platform. It has been tested on a residential building BIM model and proofed high accuracy and reliability in checking compliance with credit criteria of TARSHEED rating system.

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